CANADA

GEOGRAPHICAL BULLETIN

No. 19 May 1963

GEOGRAPHICAL BRANCH
Department of Mines and Technical Surveys
OTTAWA, CANADA

GEOGRAPHICAL BULLETIN

CANADA

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Ottawa, 1963

$2.00

Cat. M65-1/19

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STUDIES IN THE PHYSICAL GEOGRAPHY OF NORTH-CENTRAL BAFFIN ISLAND, N.W.T.

J. D. Ives and J. T. Andrews

ABSTRACT: Data accruing from reconnaissance field work in north-central Baffin Island and from intensive air photograph interpretation have been utilized to prepare colored maps of glacial features on scales of 1:500,000 and 1:250,000. These sheets are the first in a series of terrain analysis maps of Baffin Island; sheets for other terrain features will be compiled and published separately.

The text provides a detailed description of the maps and an analysis of the probable course of deglacierization of the Baffin Island–Foxe Basin area and lays the foundation for a long-term program of field investigation. Much of the discussion is tentative, being based upon relatively limited data from a large tract of land. Nevertheless, it is apparent that mountain glaciers played an insignificant part in the over-all glacierization of Baffin Island; that at a relatively late phase in the last glaciation a large, inland ice mass occupied most of the land west of the eastern coastal mountains, probably extending far into Foxe Basin; and that the final phases saw the westward withdrawal of this ice sheet from the regional watershed and the persistence of ice lobes in the main Foxe Basin valleys, thus resisting encroachment of the late-glacial sea. Glacial and glacio-fluvial features formed during this process are well preserved and can be related to forms under construction around the present margins of the Barnes Ice Cap. The concept of deglacierization under arctic climate conditions is introduced as a logical approach to an understanding of features formed adjacent to and beneath a cold ice sheet. One of the most outstanding discoveries is the Cockburn end-moraine system, which extends for more than 400 miles, roughly parallel to the heads of the Baffin Bay fiords; this system has been related to a late-phase stand of the inland ice.

RÉSUMÉ—Les données recueillies au cours de travaux de reconnaissance exécutés dans le Nord de la partie centrale de l'île Baffin et celles qu'on a obtenues par l'interprétation minutieuse des photos aériennes ont servi à préparer des cartes en couleurs au 500,000e et au 250,000e qui donnent un aperçu des formes glaciaires. Ces cartes sont les premières d'une série qui porte sur l'analyse des formes du relief de l'île Baffin. Les cartes relatives aux autres caractéristiques du terrain vont être rédigées et publiées séparément.

Le texte du rapport fournit une description détaillée des cartes et une analyse des étapes probables de la déglaciation de la région de l'île Baffin et du bassin Foxe; il établit le fondement d'une campagne à long terme de travaux de recherches sur le terrain. Une bonne partie de l'étude est de nature hypothétique en ce qu'elle se fonde sur des données relativement restreintes au regard d'une si grande étendue de terrain. Néanmoins, il semble que les glaciers de type alpin aient joué un rôle de peu d'importance dans le processus de glaciation de l'île Baffin. Il semble également que, vers la fin de la dernière glaciation, une vaste calotte glaciaire continentale ait occupé la majeure partie du terrain situé à l'ouest des monts de la côte orientale, s'étendant probablement assez loin à l'intérieur du bassin Foxe. Selon toute évidence, les phases tardives de la glaciation auraient donné lieu à une récession des glaces en direction ouest à partir du réseau de drainage régional et à la persistance de lobes glaciaires dans les principales vallées du bassin Foxe; cela aurait eu pour effet d'empêcher une invasion de la mer à la fin de l'époque glaciaire. Les formes glaciaires et fluvio-glaciaires qui ont pris naissance pendant ce processus sont bien préservées et peuvent être rattachées à des formes présentement en voie de constitution autour des rebords actuels de la calotte glaciaire Barnes. Les auteurs proposent l'idée de la déglaciation dans des conditions particulières à un climat arctique comme hypothèse

MS submitted April 1962.

logique pour expliquer les caractéristiques des formes attenantes ou sous-jacentes à une calotte de glace. Parmi les découvertes les plus remarquables, il convient de signaler le réseau de moraines terminales Cockburn, qui s'étend sur une distance de plus de 400 milles, à peu près parallèle aux fonds des fiords de la baie Baffin et qui serait relié à une avancée tardive de la calotte glaciaire continentale.

INTRODUCTION

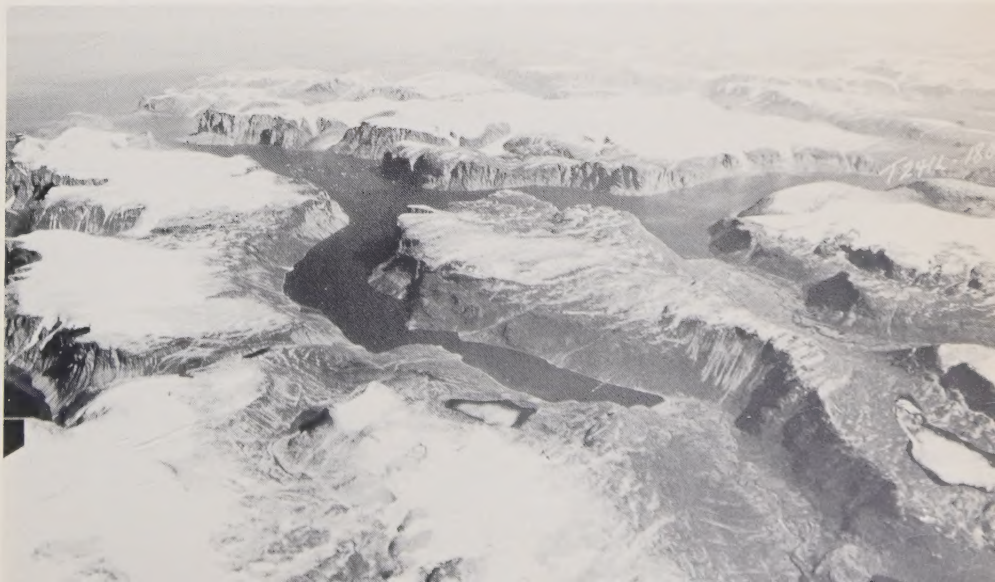
This paper embodies a map of glacial features and an evaluation of field and air-photograph data of a large tract of north-central Baffin Island represented on the Cockburn Land 1:500,000 map sheet (Figure 1 in pocket). The intention is to provide a graphic description of glacial landforms found in the area, and to lay the framework for more detailed studies to be carried out in the future by the Geographical Branch. It contains a vital part of the terrain analysis of the Cockburn Land map sheet, and is the first of a series of maps and texts designed to portray as accurately as possible the physique of this type area of the eastern Canadian Arctic.

The Cockburn Land and Clyde 1:500,000 map sheets, and the two neighboring map sheets to the south (Foxe Basin North and Home Bay) embrace a cross-section of Baffin Island, including the Barnes Ice Cap. The area has been selected for long-term study of all relevant aspects of physical geography, glaciology and geomorphology in particular. A permanent building was acquired by the Geographical Branch at Longstaff Bluff in 1962 and Parcol huts for field base camps were also set up. These were located on the crest of the Barnes Ice Cap and on the upper King River which drains the ice cap's northwestern sector. The work described below represents a preliminary report on some of the main aspects of the initial 1961 reconnaissance expedition carried out by the writers and Dr. V. W. Sim and 2 assistants. During the 1962 season, a total of 12 geographers and assistants began more detailed studies in glaciology and geomorphology. The results of this second phase of the reconnaissance will be published in later issues of this Bulletin and elsewhere.

During 1961 only 3 relatively small field areas on the Cockburn Land map sheet were investigated by the writers, and it proved impossible at that time to visit the important eastern sectors of the area. However, sufficient ground control was obtained which, added to the airborne reconnaissance and the interpretation of high-quality vertical air photographs, permits the reliable plotting of many of the glacial features and the initial formulation of a series of working hypotheses outlining the recent evolution of the area. Areas studied in the field include the northwest margins of the Barnes Ice

FIGURE 3. Looking northwest from Cape Adair on the Baffin Bay coast. A narrow strip of continental foreland with raised marine beaches lies at the foot of the eastern arctic mountain rim. The Bruce Mountains exceed 5,500 feet and Cambridge and Dexterity fiords cut through them in the middle distance. A landing was made on the long lake in August 1962 and the highest marine feature was measured as approximately 60 feet above sea level. *Photo: RCAF oblique No. T254L-230, 30 July 1948.*

FIGURE 4. Photograph shows Rannoch Arm and the middle reaches of Cambridge Fiord with Baffin Bay and the Bruce Mountains in the distance. The massive inter-fiord areas have the appearance of an uplifted and dissected erosion surface. The foreground is the transition zone between the mountains and the interior uplands. *Photo: RCAF oblique No. T241L-180, 30 July 1948.*



Cap, the east coast of Steensby Inlet in the vicinity of the Rowley River, and the Rimrock Lake area where the field party's base camp was set up in lat. 70°41' N. long. 75°15' W.

Physical Setting

The present landscape of north-central Baffin Island is still essentially in the grip of the last ice age. Strict application of glacial nomenclature is not intended but it is illogical to refer to a postglacial period when so much of the area is still mantled with glacier ice. The map sheet provides a cross section of Baffin Island, from Baffin Bay in the northeast, to Steensby Inlet and Foxe Basin in the southwest. The area may be divided broadly into 4 major geomorphological provinces: the eastern continental foreland, the eastern arctic mountain rim, the interior uplands and the Foxe Basin lowlands. This four-fold generalized subdivision holds good for the 'waist' of Baffin Island whereas in the northwest of the area under study the occurrence of plateaux and vales underlain by Palaeozoic sedimentary rocks adds a complication. With this exception, the scanty knowledge of the bedrock geology indicates that the north-central tract of Baffin Island is underlain principally by an acidic suite of Archaean granites and granite-gneisses.

The continental foreland, best developed in the 'Clyde', 'Isabella' and Henry Kater peninsulas, is not well represented on the Cockburn Land map sheet. Apart from a narrow coastal lowland fringe south of Cape Hunter and north of Buchan Gulf, the eastern arctic mountain rim rises abruptly from the waters of Baffin Bay. Its width is between forty and fifty miles and many individual summits exceed 5,000 feet (Figure 3). The whole may be described as a difficult mountain country completely cut through by a network of fiords, troughs and transection valleys, with magnificent Lofoten-type peaks, arêtes and tinds rising above them. The broader, inter-fiord areas are heavily glacierized and many types of glacier ice are included, embracing plateau ice caps, transection glaciers, valley and outlet glaciers, cirque glaciers and small, thin, isolated ice patches.

A striking feature of the geomorphology of the eastern arctic mountain rim is the apparent accordance of summit level with an over-all south-westerly slope. A study of the aerial radar altimetry profiles* reveals that the highest summits lie close to Baffin Bay and that heights are lower toward

*Radar altimetry information supplied by Radar Altimetry Section, Topographical Survey, Dept. Mines and Tech. Surv., Ottawa.

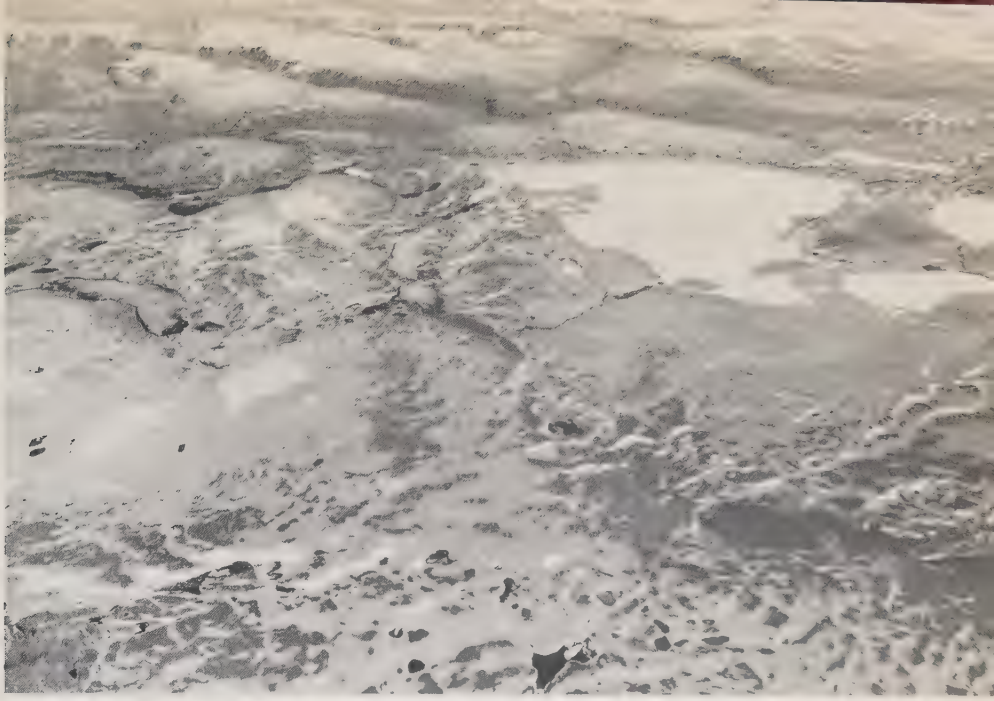


FIGURE 5. Looking eastward from the interior uplands across the heads of Cambridge and Dexterity fiords into the eastern arctic mountain rim. Note the gradual transition between the two geomorphic provinces. The light-toned terrain surrounding the wasting plateau ice patches are due to restricted rock-lichen growth in areas recently uncovered by melting ice and snow. The widespread occurrence of ice-wedge polygons is a remarkable characteristic of the foreground. *Photo: RCAF oblique No. T241-195, 30 July 1948.*

FIGURE 6. Ground view of the interior uplands north of the Barnes Ice Cap. Note the gentle rolling hills rising individually above the general level and the broad, open valleys. The Isortoq River valley crosses the middle ground and the pronounced upper limit of the lighter-toned area marks the shoreline of a former ice-dammed lake (glacial lake Lewis). The area is mantled with fields of boulders as seen in the foreground. *Photo: J.D.I. 61-83, 19 July 1961.*

FIGURE 7. View looking eastward across the interior uplands and the northern margin of the Barnes Ice Cap. In the foreground the Lewis Glacier is bordered by a complex of well-developed, glacial, drainage channels. The small lake southwest of centre was used as a base of operations for the field party in August 1961. In the distance, the ice-dammed lakes (Conn and Bieler lakes) are living evidence that such vast bodies of water (up to 40 miles long) can exist in frontal positions. This aerial example is regarded as a natural, small-scale model of late-glacial conditions in northeastern Labrador-Ungava. Note the virtual absence of firn on the ice cap. *Photo: RCAF oblique No. T241L-215, 30 July 1948.*

the southwest. Within the mountain area relief frequently exceeds 5,000 feet. This gives the appearance of an old, uplifted erosion surface which has been deeply dissected, first by fluvial, and later by glacial processes (Figures 3 and 4). This simplified description is intended to do nothing more than provide an impression of the landscape; undoubtedly the evolution of the area is much more complicated.

Toward the southwest the relief becomes much more subdued and the general elevations lower. In the vicinity of the heads of the longer fiords (Cambridge and Gibbs fiords) the transition occurs to the interior uplands (Figure 5); here elevations reach 3,000 feet on broadly convex summits and, away from the fiords, relief rarely exceeds 1,000 feet. Whether this transition marks a break between two generations of summit surfaces, or whether it is merely a reflection of decreasing efficacy of erosional processes on the same surface with increasing distance from base level and decreasing elevation, is a major geomorphological problem awaiting field investigation and more detailed topographic mapping. The interior uplands are rolling to flat over wide areas. Elevations exceed 3,000 feet in the northeast and descend to below 1,000 feet in the southwest. Broad, shallow valleys cut through the central tract (Figure 6) and the watershed lies close to Baffin Bay tidewater. The Isortoq River rises only 16 miles from the head of Clark Fiord, and the Rowley River rises within 20 miles of Cambridge Fiord. One exception to this is the anomalous drainage caused by the location of the Barnes Ice Cap, which straddles the interior uplands well west of the normal height-of-land. The watershed, therefore, is locally transferred to its crest line (Figure 7).

The long, sub-parallel Foxe Basin drainage provokes the impression of former consequent streams superimposed from a sedimentary cover onto the underlying basement complex, while the abrupt changes of course of some of the rivers implies a degree of adjustment to structure. Between the major streams the interior presents a desolation of massive boulder fields on long gentle slopes dipping imperceptibly southwestward. Occasional, rounded hills rise 300 to 500 feet above this general upland surface. These are common to the northeast and present a rolling aspect to the landscape. In the interior they are comparatively infrequent; west of Rimrock Lake they have not been encountered to date. As with the mountain rim, the first impression of the landscape of the interior uplands indicates a complicated geomorphological history. More precise analysis must await detailed research.

The southwestern limit of the interior uplands abuts in places onto Steensby Inlet and striking coastal cliffs occur. However, north of Steensby Inlet, and especially between Nina Bang and Patlok lakes, low, lake-strewn, till-covered terrain is typical. This area is classified with the Foxe Basin lowlands, more characteristically represented by the flat limestone plains between Neergard Lake and Steensby Inlet.

The northwestern corner of the map sheet is characterized by a plateau, scarp and vale landscape with first, limestone outliers, and then the main sedimentary province overlying the basement complex and indicating that it was once much more extensive than today.

It is upon this physical setting—Baffin Bay, continental foreland, eastern arctic mountain rim, interior uplands, Foxe Basin lowlands, Foxe Basin—that glaciation has occurred, has influenced the landscape, and has been influenced by it.

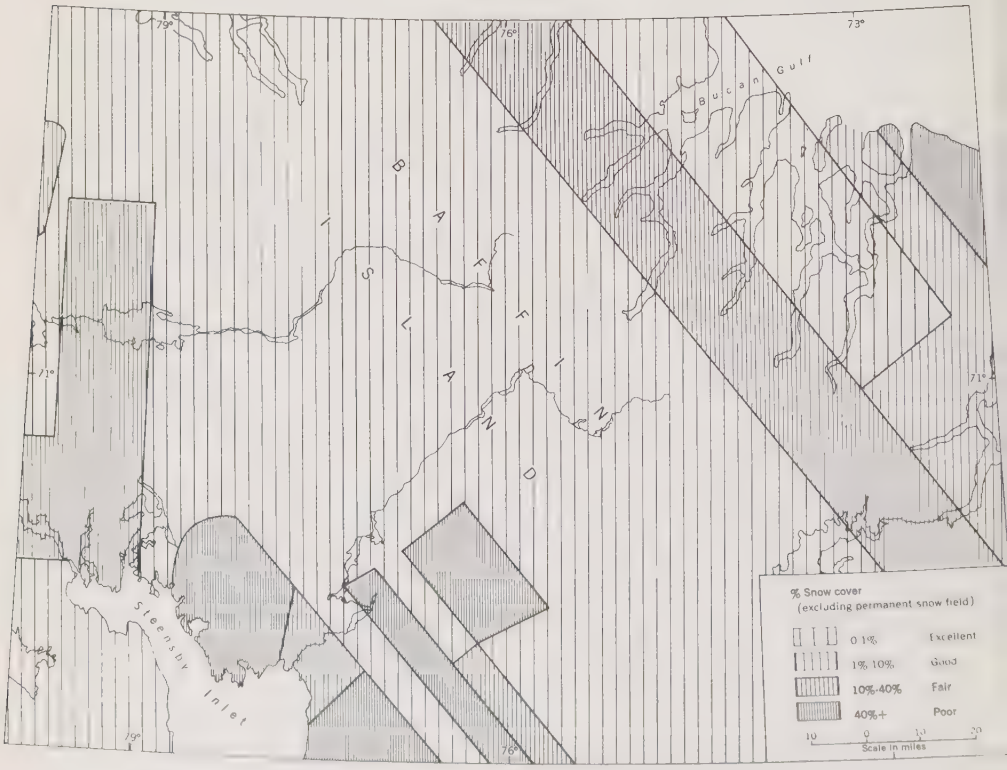


FIGURE 8. Map showing the quality of air photograph coverage for the Cockburn Land 1:500,000 map sheet.

Emphasis is placed upon the existence of the high eastern mountain rim cut by fiords so that no section lies far from deep water. Summits rise above 5,000 feet yet little total land area exceeds 1,500 feet. In contrast, the vast interior uplands, with large areas between 1,500 and 2,500 feet, have restricted access for glacial discharge towards Baffin Bay, and are backed by a broad, shallow inland sea, Foxe Basin, which probably drained during the initial glacial eustatic lowering of world sea level. The broad elements of the physique of Baffin Island are partially paralleled in north-eastern Labrador-Ungava; similarly, many aspects of the glacierization and deglacierization appear to have followed broadly parallel trends in the two areas. As much more is known of the glaciation of Labrador-Ungava (Ives, 1960a; Andrews and Matthew, 1961; Løken, 1962a and b), working hypotheses evolved for this area will be applied to, and tested against, the Baffin Island data. In addition, the work of R. P. Goldthwait (1950, 1951) between the Barnes Ice Cap and Baffin Bay has provided an invaluable starting point for the present study.

MAP OF GLACIAL FEATURES

Terrain Analysis Series: Cockburn Land 1 : 500,000 Sheet

Map Compilation

Glacial and topographic details are shown on maps at the scale of 1:500,000 and 1:250,000 and are included as Figures 1 and 2 (in pocket). Initially, reconnaissance mapping was completed before the field season using vertical air photographs flown in 1958 from 30,000 feet and trimetrogon photography flown from 20,000 feet in 1948 and 1949. Complete vertical coverage is available and the quality is excellent for much of the area. However, two flight lines in the northeast, and several to the southwest between the Barnes Ice Cap and Steensby Inlet were flown in June when an average 70 per cent snow cover existed. Quality of photography, and hence, a measure of the degree of reliability of the photograph interpretation, are shown in Figure 8. In 1961, part of the area was reflown under excellent conditions between July 19th and July 27th, and the resulting photographs serve to offset much of the existing poor coverage.

Actual field checking of the photograph interpretation was limited to the three areas* specified above, and scattered airborne reconnaissance.

*The northwest margins of the Barnes Ice Cap, the east coast of Steensby Inlet in the vicinity of the Rowley River and the Rimrock Lake area, lat. 70° 41' N, long. 70 15' W.

With the exception of the important Cockburn end-moraine belt, a cross-section of most of the glacial features was closely field-checked, so that the limitations of small area field coverage were compensated for to a large degree.

Following the field season, base maps were prepared at the scale of 1:125,000 from photographic enlargements of the 1:500,000 map sheet, and the entire map area was re-interpreted. Thus, complete photograph coverage has been examined twice, and independently, by each of the writers as a careful cross-check of the accuracy of the interpretation. Data collected in the field were plotted on scales of approximately 1:30,000 on planimetric maps drawn from air photographs in the photogrammetric laboratory of the Geographical Branch. The data assembled on the base maps were then reduced in two stages to the scale of 1:500,000 and a single map sheet compiled. This reduction resulted in an enforced degree of generalization; in order to compensate for the subjective element in this generalization, Figure 2 at 1:250,000 was compiled and reproduced for the southeastern quadrant. While slight generalization was necessary in this case, the map is regarded essentially as a factual portrayal of features shown on the air photographs. Comparison with the main map will indicate clearly the degree of generalization inherent in its compilation and will allow an appraisal of the writers' justification in the preliminary interpretation of the map which follows. The southeastern quadrant was selected for compilation at 1:250,000 because of the great wealth of detail present in this area. (*See Map Notes in this Bulletin for further description of this map.*)

Features plotted from the air photographs and field work include glacial, glacio-lacustrine and glacio-fluvial forms (*see* key to Figures 1 and 2 in pocket). In addition, marine forms, glacial striations, limestone erratics and existing glacier ice are shown. The distribution of forms such as striations and limestone erratics is naturally limited by the extent of the actual field work. Glacial directions have been determined in the field, and in some cases have been inferred from the air photographs. Many glacio-lacustrine and glacio-fluvial features have been omitted in the upper valley of the Isortoq River to avoid confusion of detail. Here, a minimum of seven terraces occur, the lower being interpreted as glacio-lacustrine, the upper as glacio-fluvial; these will be discussed in detail in a study of the Rimrock Lake field area (Ives, 1964).

FIGURE 9. Photograph showing part of the Cockburn end-moraine system which lies to the east of Conn and Bieler lakes. Note the small, wasting ice patch in the lower right corner and the light-toned, recently uncovered area around it. *Photo: RCAF vertical No. A17047-156, 24 July 1961.*

FIGURE 10. Photograph showing the juxtaposition of a lobe of the Cockburn end-moraine system (lower right) and the present mountain glacierization. This view is looking eastward into Itirbilung Fiord, south of the map area. Henry Kater Peninsula can be seen in the centre background. *Photo: RCAF oblique No. T216 R224, 5 July 1948.*

Glacial Features

1. *End-moraine systems*—The most striking series of features emerging from the air photograph interpretation is what is here referred to as the Cockburn end-moraine system (Figures 9 and 10). It occurs just inland of the heads of the Baffin Bay fiords and extends as a broad belt of closely spaced, individual, morainic arcs extending from the southeast corner of the map sheet (southeast of Bieler Lake) roughly northwestward to within a few miles of the ice-dammed lake at the head of North Arm before curving to trend more nearly due west along latitude 71°38' N. Inland from Tay Sound and Paquet Bay, in the northwest, it is much more diffuse, partly because of the confusion of high plateau and vale, while in the southeast part of the map sheet it forms a distinct belt 8 to 16 miles wide. Here the eastern, or outermost members loop around the foothills of the eastern arctic mountain rim and, in places send off-shoots as lateral and end-morainic lobes into the heads of the fiords. Individual ridges rise as much as 50 to 150 feet above the surrounding terrain. The inner, or southwestern, margin of the morainic system lies entirely back from the heads of the fiords and in many places closely coincides with the watershed. Southwest of the watershed and in the main valleys, a transition occurs from end-moraine ridges to cross-valley moraine ridges, glacial lake shorelines and kame terraces (Figure 2) though on the uplands proper, the end moraines can be traced to within 8 miles of the present margin of the Barnes Ice Cap.

Preliminary examination of the air photographs of the whole of Baffin Island led to the realization that the Cockburn end-moraine system is continuous over a distance of more than 400 miles and can be followed southward to the west of the Penny Ice Cap. The generalized distribution of moraines in Baffin Island is shown as Figure 11 and an interpretation of this distribution follows.

The Cockburn end-moraine system probably represents the frontal location of an important still-stand or readvance phase of the Wisconsin Baffin Island inland ice. At the greatest extent of this still-stand, or more logically, series of minor phases of still-stand and readvance, outlet glaciers flowed off the interior uplands into the Baffin Bay fiords. They were 1,500 to 2,000 feet thick over the heads of the present fiords. It is probable that, at this phase, the inland ice extended southwestward into Foxe Basin. No definite correlation can yet be made, although additional evidence is presented. During the final phase, the northeastern inland ice margin was entirely on land and large sandar were deposited, and subsequently terraced, in the valleys and gorges leading down to tidewater.

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FIGURE 11. The distribution of major end and lateral moraines in Baffin Island, compiled from air photograph interpretation and scattered field observations. The moraines are shown very schematically and many important, but short stretches have been omitted because of scale limitations. The Cockburn system is not differentiated but forms the conspicuous belt roughly parallel with the heads of the Baffin Bay fiords.

FIGURE 12. Photograph showing a section of the Separation Lake moraine trending obliquely across the lower right. Lower down the hillside (i. e. to the NW) occur lateral zones of glaciated pavement followed by small morainic ridges and ultimately by a complex of glacial drainage channels, kame terraces and kettle holes. The section of Separation Lake shown is a series of vast kettle holes. A remarkable pitted delta is shown slightly northeast of centre. Its north-facing ice-contact slope is shown in Figure 16. *Photo, RCAF vertical No. A15849-32, 24 August 1957.*

Nothing strictly comparable to the Cockburn end-moraine system, regarding degree of development and close proximity of individual ridges, is to be found southwest of the Barnes Ice Cap. However, many stretches of end moraine and lateral moraine occur, although they are more widely spread. A major system can be traced from the southeast side of Separation Lake for a distance of nearly 16 miles to within 4 miles of Steensby Inlet (Figure 12). Outwash, extending from behind this system, can be traced to the coastal sector and has been graded to below the level of maximum marine submergence. A comparable system of lateral/end moraines is found in the vicinity of Isortoq Lake; this has been traced for more than 20 miles. Between the Isortoq Lake moraines and the Barnes Ice Cap, many morainic arcs occur. They are also present south of the southern limit of the map sheet. Whether the Isortoq-Separation lakes moraine systems coincide with the inner, more recent parts of the Cockburn system cannot be determined so far. Individual morainic ridges between them and the present margin of the ice cap, some 50 miles distant, presumably represent temporary halts or reversals of trend in the successive late-glacial shrinkage of the proto-Barnes Ice Cap. End moraines, 8 to 16 miles long, trending east-west, have also been traced on the west side of Steensby Inlet.

End moraines associated with the existing valley glaciers and ice caps of the eastern arctic mountain rim are abundant, but are rarely found more than a few hundred yards to a mile beyond the present glacier snouts. They appear very fresh and most may be ice-cored; therefore, they probably mark a relatively recent stand of the coastal glaciers (*see* Falconer, 1962). It is extremely important to note that this restricted distribution of coastal glacier moraines contrasts sharply with that of the former inland ice marginal features. It is postulated that the coastal glacierization may never have been much more extensive than today and, as in northeastern Labrador-Ungava (Ives, 1960a and b), glacierization on the inland plateau west of the mountains may have been much more important, especially in the deglacierization phases.

2. *Lateral-moraine systems*—Lateral moraines have already been mentioned in association with the Isortoq-Separation lakes moraine systems. In the mountain sector to the northeast, however, a distinct system of lateral moraines has been plotted from air photographs. These occur along the sides of the Baffin Bay fiords, in the inner zone, to within 3,000 to 3,500 feet above sea level, and in the outer zone, to within a few hundred

feet of sea level. They are frequently poorly developed or poorly preserved or both, probably on account of steepness of slope. They may merely represent the oldest, outermost phase of the Cockburn end-moraine system, or they may be related to a discrete glacial phase. Thus they are considered separately. Their locations indicate that they were formed when the entire Baffin Island interior, and probably also, Foxe Basin, was inundated by an expanded ice sheet of sub-continental proportions, which sent massive outlet glaciers down the entire lengths of the fiords to calve directly into Baffin Bay. At this time coastal mountain glacierization was possibly even less extensive than today in areas where the inland ice and its outlet system dominated. North of Buchan Gulf, an independent and relatively extensive centre of dispersal probably existed, and an expanded Penny Ice Cap far south of the map area probably also held its own against the onset of ice from the west.

In many fiord localities (e.g., Clark Fiord, Dexterity Fiord, Coutts Inlet and North Arm), and on the southwestern side of the mountain zone, the coastal mountain glaciers have apparently expanded after the melting of the inland ice as existing valley glaciers have trenched the old lateral moraines on the fiord walls.

3. *Glacial lichen-trim zones*—Although not shown on Figures 1 and 2, this phenomenon is described here because, especially in the case of the small plateau ice patches which have not formed moraines, the lichen-trim zones are the virtual equivalent of end-moraine systems. The light-toned areas surrounding ice patches and small ice caps are very conspicuous on the air photographs (Figure 5). The difference in tone is due to slight growth of rock lichens as compared with the more distant areas which have been available for lichen colonization for a much longer period. Similarly, about 70 per cent of the interior uplands on the Cockburn Land map sheet is occupied by comparable light-toned areas which are believed to represent the former sites of permanent ice and snow patches which have melted away during the last 2 or 3 centuries (Ives, 1962). A similar occurrence is seen in association with former ice-dammed lakes, and existing ice-dammed lakes which have experienced recent lowering in level due to thinning and recession of the ice dam. This contrast in lichen growth can be utilized to obtain relative and actual ages of the associated geomorphic features (Beschel, 1961), and, with respect to the ice caps, it serves to give a measure of the recent recession.

4. *Cross-valley morainic ridges*—Many of the valleys in the environs of the Barnes Ice Cap contain innumerable, irregular and sub-parallel ridges trending perpendicular to the axis of the valley (Figure 2, in pocket)*. Examples of such ridges have been examined in some detail in the Rimrock and upper Isortoq valleys but a full explanation of their origin cannot yet be attempted. They appear to be associated with former ice-dammed lakes, or at least with waterlogged ice, as their occurrence is restricted to those areas where ice thinned back from the regional or local watershed.* They are composed in places of coarse, angular till with a pronounced particle orientation perpendicular to the axis of the ridge crest; in other localities, however, stratified sands and gravels were exposed and the ridges have the superficial morphology of sub-glacially engorged eskers (Mannerfelt, 1945). It is perhaps significant that they are restricted to the drainage basin of the Isortoq River and the area between the Barnes Ice Cap and the Cockburn end-moraine system, although there are minor exceptions to this. Also, Goldthwait considers that they may be forming today beneath the waters of Generator Lake, either at the ice margin, or sub-glacially beneath it (Goldthwait, personal communication, 1961). From the detailed till-fabric analyses so far completed, it would appear likely that these features are formed sub-glacially and may bear some relationship to the De Geer moraines (Hoppe, 1960). The problem will be explored in detail in later publications, and their form will then be shown more adequately; on the terrain maps only the area covered by them is represented, as the scale does not permit anything more elaborate. In several localities west of Steensby Inlet, and below the marine limit, there are groups of linear ridges which resemble the De Geer moraines of Hoppe (1960).

5. *'Dead-ice' moraine*—Broad areas between Nina Bang and Inuktorfik lakes are characterized by a low-lying, irregular terrain which appears on the air photographs as a till landscape with numerous kettle holes (Figure 1). The contours are very gentle; this may be the result of a former marine incursion. Small patches also occur between Patlok Lake and Tay Sound. North and west of the head of Steensby Inlet, similar terrain, principally in sand and therefore more aptly described as modified kame and kettle topography, occurs over wide areas. These two forms are described together here but are differentiated on the map because of the assumed material composition. They may represent the sites of former wasting bodies of stagnant ice.

*See Andrews, J. T., in this Bulletin.

6. *Glacial flow features*—Till lineations, crag-and-tail features, and rock drumlins, have been plotted from air photographs (Figure 13). Ground observation has allowed precise determination of direction of flow in some instances, and occasionally direction has been inferred from the photographs. Till drumlins do not occur as such except west of Steensby Inlet, but elongate furrows and ridges are conspicuous and may be classified as drumlinoids. These are especially conspicuous on the air photographs where the light-toned areas of limited lichen growth, resulting from recent persistence of snow and ice in the furrows, contrast with the linear crests. Flow features of this nature are largely confined to the area east of longitude 79° W. and south of latitude 71° N., although indistinct sets occur farther north. Practically all occurrences mapped, trend southwest to northeast and in some sectors, notably northeastward from Isortoq Lake, can be traced over distances of more than 50 miles. In the Rimrock Lake field area, *roches moutonnées*, striations and crag-and-tail features indicate movement toward the northeast, and accordingly the set of lineations northeast from

FIGURE 13. Photograph showing glacial lineations and rock drumlins(?) along the course of the Freshney River; it is proposed that the ice movement was obliquely from left to right. Note also the distinct change from bedrock to till-covered hill slope to the north of the flow features. This is interpreted as a meltwater trim-line. Small glacial drainage channels occur above it to the northwest of centre. *Photo: RCAF vertical No. A16302-8, 29 August 1958.*

Isortoq Lake is taken to indicate regional ice movement in this direction. Toward the southeast, and ultimately to the very margin of the ice cap in latitude 70° N., this same northeasterly trend can be followed. Here movement *in* toward the existing ice cap is interpreted from the morphology of the linears on the air photographs. Similarly, the same trend is again occurring on the opposite side of the ice cap, south of Bieler Lake.

Additional partial evidence of a northeasterly regional movement is found in the occurrence of limestone erratics along the middle reaches of the Isortoq River. Although the source area cannot be assigned with certainty, the Foxe Basin coast, or the northwest corner of the map area, appear as the only alternatives. Sim has also discovered limestone erratics in a broad zone in the vicinity of latitude 69° N. and to within a few miles of tidewater in Home Bay (Sim, personal communication, 1961). It appears likely that the entire waist of Baffin Island has experienced regional flow toward the northeast from an ice-divide situated over the present Foxe Basin coast, or else further westward over Foxe Basin itself.

In the Rimrock and Striding valleys individual sets of striations indicate that localized flow patterns at a later date were controlled by the topography, presumably during the final shrinking phases of the proto-Barnes Ice Cap. A second area of more complicated flow patterns exists in the Separation Lake-Steensby Inlet area. Glacial lineations westward of longitude 77° W. in this locality are, to within 5 degrees, parallel to the Isortoq Lake set farther east. However, field observations, and crag-and-tail forms on the air photographs indicate that the final direction of flow was emphatically toward the southwest, implying the existence of an ice-divide between Separation and Rimrock lakes. The pattern is further complicated by the great abundance of limestone erratics between Separation Lake and Steensby Inlet, and coastal observation of striations trending northwest to southeast. Instances of superimposition of the two sets, at right angles, were found, although it was not possible to determine their relative age. Along the Foxe Basin shore south of the Rowley River, limestone erratics were so abundant that it was possible to walk for scores of paces at a time using the limestone blocks as stepping stones. As limestone outcrops to the west and northwest across Steensby Inlet, and as no occurrence of limestone upstream of the southwesterly trend is known, it is presumed that a relatively late movement of ice from the northwest brought

FIGURE 14. Telephoto view of part of a delta succession in the upper Isortoq River valley. In the foreground, adjacent to the river, central kames and cross-valley moraines occur. Immediately above lies a dissected delta coincident with a glacial lake shoreline at 1,419 feet above sea level. Next in the succession up-slope lies a delta at the level of glacial lake Lewis (1,658 ft.) and beyond that in the distance the 1,820-ft. kame-delta. *Photo: J.D.I. 61-234, 21 July 1961.*

the limestone erratics into the Separation Lake area and caused the striations which cross the southwesterly trending set. West of Steensby Inlet well-developed drumlins and drumlinoids indicate ice movement from the interior toward the south into Murray Maxwell Bay. This pattern, also depicted by Blackadar (1958), is somewhat fan-shaped and may represent part of the ice stream which deposited the limestone erratics on the east side of Steensby Inlet. Alternatively, the fragmentary flow pattern is highly suggestive of the development of a large calving bay (Hoppe, 1957 and 1960) centred on late-glacial Steensby Inlet. Striations and lineations range in trend from southwest to south over a distance of 50 miles between Isortoq Lake and the lower Cockburn River (Figure 1). This seems logical in consideration of the existing knowledge of the pattern of marine incursion and general late-glacial conditions and corresponds to well-established examples in Sweden (Bergdahl, 1959; Hoppe, 1960). However, the problem requires a much more thorough field investigation.

7. *Kame terraces and associated features* South and west of the regional watershed, end- and lateral-moraine systems are virtually replaced by extensive occurrences of kame terraces and associated glacio-fluvial features. This is particularly true of the upper valleys and tributaries of the Isortoq, Rowley and Pilik rivers (Figures 1, 6 and 14). In the upper Isortoq valley, a

transition occurs on the watershed from the Cockburn end-moraine system to a series of kame terraces and glacial lake shorelines at various levels, whereas in the Rowley and Pilik drainage systems, kame terraces converge upon the cols into broad, dry valleys, which are interpreted as direct meltwater overflows. The pattern is particularly noticeable in the case of the Pilik drainage system and a further characteristic is that the kame terraces are largely confined to the north-bank tributaries. It is suggested that this major terrace system represents a specific phase in the process of deglacierization; that it marks a time when the inland ice margin had receded to the south and southwest of the regional watershed. A logical interpretation seems to be that as thinning and concomitant recession of the margin of the inland ice occurred, with the regional slope of the ice up toward the southwest over the watershed area, the position was reached when the major cols became ice-free and the ice, at least along its northern margins, became stagnant. Drainage of meltwater occurred for a time laterally along the margins of tongues of ice which occupied the upper valleys of these southwesterly flowing streams, spilling northward and northeastward into Eclipse Sound and Baffin Bay tidewater, respectively. At this phase also, the outwash, laid down earlier in the valleys beyond these cols, was dissected into unpaired terraces by the meltwater once the heavy glacial load was trapped southwest of the watershed. Associated with the main kame terrace system are perched deltas, kame-delta-terraces and glacial lake shorelines.

Virtual absence of kame terraces in the south-bank tributaries of the Pilik River, and the presence of an abundance of glacial drainage channels sloping down valley, give the impression that the northern margin of the inland ice was withdrawing southward, or southwestward in a fairly regular manner. However, in the main valley, paired kame terraces, deltas and stretches of glacial lake shoreline, indicate that ice in the valley bottom may have become detached from the main inland ice, and thereafter melted in situ. This hypothesis is strengthened by comparison with the existing northern margin of the Barnes Ice Cap (Figures 7 and 15). The ice cap has negative temperatures and is therefore frozen to its bed, at least along its periphery. The surface slope is very gentle, while the margin is receding upslope. In such a situation, movement is probably negligible and the developing glacio-fluvial landforms provide a picture akin to dead-ice

FIGURE 15. View toward the southeast showing the gentle slope of the feathering northern margin of the Barnes Ice Cap. To the left of the picture the surface moraine merges imperceptibly into ground moraine and the actual ice edge cannot be distinguished. *Photo: J.T.A. 61-13-4, 14 August 1961.*

conditions rather than to those of an individual, active ice mass such as the Barnes Ice Cap. This concept is discussed in more detail in the section on glacial drainage channels.

A similar situation appears to have occurred in the upper Rowley River drainage system. Although not so pronounced in this case, the features indicating ponded or restricted meltwater, such as kame terraces and glacial lake shorelines, are largely confined to south-facing valleys, while north-facing valleys contain numerous drainage channels. The development of paired terraces on the floor of the main valley, however, also with pitted outwash aprons, indicates the isolation of ice masses in the valley bottom as the ice-cap margin receded southward.

In the lower valleys of the Isortoq, Rowley and Pilik rivers, the situation was somewhat different as the margin of the inland ice was receding up the regional slope of the land. However, extensive pitted sandar and kame terraces indicate that glacio-fluvial processes predominated over glacial activity and that large blocks of detached ice melted independently in the deeper valleys. Separation Lake, for instance, is a series of massive kettle holes (Figures 12 and 16).

As previously mentioned, some of the kame terraces and outwash plains east of Steensby Inlet are graded to a datum below the marine limit, which is 315 feet in this area.* It is evident that the Foxe Basin coast emerged from glacial inundation before the interior, and that a complicated relationship between deglacierization and marine submergence existed, with tongues of ice in some of the valleys prohibiting access of the sea and presumably calving into it.

In the upper Isortoq valley, the kame terrace pattern is extremely complicated. Gradations from kame terrace, to perched delta, to glacial lake shoreline, and finally to lateral and end moraines occur. There are at least seven distinct terrace levels. The upper sets are interpreted as kame terraces with glacial lake shorelines in minor association. These are comparable in degree of development to the Rowley and Pilik kame terrace systems, although there is an important difference in distribution. In the upper Isortoq valley the kame terraces occur on both sides of the main valley as well as in the north- and south-bank-tributary valleys. Where the main stream turns abruptly to flow southward, immediately below the

*This figure is the mean of six aneroid measurements taken within 15 minutes walking distance of the high-tide datum. The individual measurements were corrected for temperature and the mean figure is believed to be accurate to within ± 5 feet.

FIGURE 16. View to the southwest at the lower end of Separation Lake showing part of the pitted delta and the north-facing ice-contact slope referred to in caption to Figure 12. The rock outcrop in the right middle background is strongly grooved and striated indicating a southwesterly ice flow. The far hillslope is littered with kame terraces and glacial drainage channels. *Photo: J.D.I. 61-188, 18 August 1961.*

Rimrock River confluence, the upper terrace systems terminate. Here the ice in the valley bottom presumably merged with the main mass of the inland ice, and the hillsides on either hand were still inundated. Drainage conditions at the upper terrace phases would indicate that, as the inland ice margin receded toward the south, the deeply incised nature of the upper Isortoq ensured that the valley rim on the south side emerged through the thinning ice, leaving an ice mass in the valley bottom. This ice mass would be connected at the Rimrock River confluence with the main inland ice. Meltwater drainage would proceed generally westward across a variety of local cols and eventually over the western Rimrock cols into the headwaters of the Freshney River. Local reversals of this trend occurred, dependent upon the topography at the ice margins, and some water undoubtedly escaped eastward, although once the ice margin had receded southward to the vicinity of the Rimrock-Isortoq confluence, the great volume escaped westward and ultimately into Foxe Basin. The progressive recession and thinning of the inland ice appears to have been extremely complicated and has been made the topic of a separate study (Ives, 1964). Successively lower terrace systems show kame terrace members more and more in the minority with glacial lake shorelines predominating. This is interpreted as indicating the existence of elongate and tributary lakes dammed against wasting ice in the floor of the main valley associated with the development of calving bays in the neighboring ice masses. The repeated succession from lateral moraine, through kame terrace forms to glacial lake shorelines along the same level is an indication of varying contemporaneous ice-marginal conditions. Meltwater at the 1,820-foot terrace level also flowed in a generally westerly direction across ice-free bedrock cols into the Freshney River and so southwestward, and the regional slope of the ice was up toward the south-southeast. A still later phase, represented by a deep lake filling the entire valley to a height of 1,658 feet indicates only a slight extension of the present margin of the Barnes Ice Cap. This lake finally drained to successively lower levels during the recent phases of Barnes Ice Cap shrinkage, approximately 200 to 350 years ago (Ives, 1962).

8. *Eskers and sandar*—Eskers are quite rare in the map area and are generally restricted to the area between Isortoq Lake and the inner Barnes Ice Cap moraine belt. Here, complicated esker and pitted outwash nets occur, indicating drainage of meltwater toward the southwest. It is the northerly extension of a field of eskers which occur extensively on the Foxe Basin North map area.

A major esker, 20 miles in length, extends from near Nina Bang Lake, south-southwestward to Steensby Inlet. Other small eskers, generally trending north-south occur on the west side of the inlet and are located almost exclusively below the marine limit; they have been modified by wave action and show a well-developed chevron-type ridge pattern. Innumerable smaller esker segments occur on many of the *sandar* and are not distinguished individually on the map.

Sandar have been referred to above and occur as outwash plains and valley trains in the lower sections of the Foxe Basin valleys and in almost all of the valleys leading into the Baffin Bay fiords. Almost the entire floor of the Isortoq valley below the Striding River confluence has a partial infilling of terraced and pitted glacial outwash.

9. *Glacial drainage channels*—All glacial drainage channels have been plotted on the glacial map, in so far as the scale permitted. In practice several channels have been shown by a single line and the direction of slope indicated where it could be adequately determined. The various types of channel, proglacial, sub-glacial, sub-lateral and lateral, are not differentiated but a special symbol is used for direct overflows and col gullies.

Most of the channels have been cut in till (Figures 1 and 7), but bedrock channels and gorges do occur, some of which are quite deep. It is believed that the deep ones have not been cut entirely during the final phase of the deglacierization. The plot of the channels and the direction of their slope provide a significant pattern; a line drawn roughly northwestward from the northern tip of the Barnes Ice Cap to the vicinity of latitude 71°31' N., longitude 79°00' W., separates channels to the northeast, with a predominantly northeastward component in their direction of slope, from those to the southwest, the slope of which indicates drainage of meltwater toward Steensby Inlet. In the northwest corner of the map area, the slope of the channels is generally down toward the northwest.

The line of demarcation between the two sets of channels is most irregular between Rimrock Lake and the Barnes Ice Cap, where it diverges far to the east. Also, many exceptions to the regional slope of the channels occur in this area, and topographic control on direction of slope is especially strong. It is significant that the demarcation line lies well to the southwest of the regional watershed (more than 50 miles distant in the Pilik and Rowley river sectors), and this divergence of glacial and permanent watershed corroborates the conclusions drawn from the occurrence of the major kame terrace and glacial lake systems. It is not suggested, however, that

this demarcation line is necessarily the site of a former ice-divide, representing a zone of divergence of flow in an ice mass. In the case of the Schefferville-Kivivic example (Ives, 1959), it was along this line that some of the last remaining blocks of stagnant ice in the form of detached masses, melted away in the valley bottoms while the intervening ridges were ice-free. In Baffin Island, however, the situation was probably very different. In the first instance, a continuation of the demarcation line toward the southeast coincides with the present crest line, or long axis, of the Barnes Ice Cap. Also, glacial drainage channels are forming today marginal to the ice cap and if its final disappearance is hypothetically envisaged, one of the indications of its former existence would be the demarcation line between two regional sets of glacial drainage channels.

A provisional interpretation of the distribution and direction of slope of the glacial drainage channels, col gullies and direct overflows is that the deglacierization was relatively consistent with the present pattern of recession at the north end of the Barnes Ice Cap. In this case, it is assumed that once the regional watershed became ice free in the northeast and northwest, a relatively orderly recession of the ice margin occurred toward the southeast. Movement within the main ice mass, along a feathering northerly margin, was limited and was at least less than the speed of recession of the margin; thus ice movement was not able to cause the obliteration of the glacio-fluvial forms. In the deeper valleys, especially where north-facing slopes were steeper than the slope of the ice surface, separation of stagnant masses probably occurred, whereas, along south-facing slopes and depending upon facility of drainage of meltwater, kame terrace systems and glacial lakes developed. In this sense only is the line of demarcation an ice-divide; along it, at successively later points in time the ice cap high was situated. Thus it probably does not represent a contemporaneous ice-divide; similarly, depending on topography, abrupt shifts in the drainage pattern would occur and the demarcation line itself, therefore, would be abruptly displaced, either to east or west. This has presumably occurred within the upper Isortoq drainage basin. Another consideration telling against contemporaneity of the divide is that the axis of the inland ice was presumably migrating slowly northeastward as the southwestern margin dissipated itself in a high-level stand of the Foxe Basin sea.

Another interesting pattern, brought out by the plotting of the channel systems, is that there are numerous flights of channels descending from broad, convex hill masses to dissect kame terrace systems in the main valleys.

FIGURE 17. A meltwater trim-line can be seen sloping from right to left across the centre ground. The foreground has been stripped almost bare by glacial meltwater leaving a bank of till 2 to 3 feet high marking its upper limit. This trim-line is associated with the 1,820-ft. terrace in the Rimrock valley. *Photo: J.T.A. 61-10-8, 24 July 1961.*

In many instances these channels could not have been nourished by meltwater from the wasting mass of the main inland ice. It is suggested, therefore, that hilltop masses, as well as valley bottom masses, became detached from the inland ice and wasted in situ. A comparison is made with the existing ice patches on summits and hill slopes, typical especially of the northern section of the map area today (Figure 5). In some cases, however, this type of channel could have been formed by run off of meltwater into calving bays which ate back into the ice margin in the valleys.

North-central Baffin Island has witnessed a deglacierization process quite distinct from central Labrador-Ungava and Scandinavia, one typified by the progressive wasting of ice masses with temperatures below the pressure melting point.

10. *Meltwater trim lines*—This term is used to describe the line below which till has been partially or completely stripped away from the bedrock (Figures 7 and 13). Both in the field, and on the air photographs, these features are sometimes very distinct for several miles and occur as a wall of till several feet high, rising above a zone of water-washed bedrock. They

are genetically related to other glacio-fluvial features such as kame terraces and drainage channels, although they presumably imply the discharge of large volumes of water, either as direct overflows, as lateral discharges, or as floods running down a main valley resulting from the drainage of an ice-dammed lake (cf. Icelandic jökulhlaup). The middle Isortoq trim lines probably originated in this way, whereas both lateral and direct situations occur in the upper valley of the Freshney River. Their distribution adds further evidence to the determination of the process of deglacierization.

11. *Marine beaches*—Marine shore features are shown on the terrain-analysis map only where they are sufficiently well developed and continuous to be plotted reasonably true to scale. Thus the major occurrence is around the shores of Steensby Inlet, where flights of beaches occur up to approximately 300 feet above high-tide limit (Figure 18). Here, field observations give a figure of 315 feet for the marine limit, and radiocarbon dates of 5,750 ± 250 and 4,700 ± 210 years* have been obtained for marine molluscs collected at 180 feet and 70 feet, respectively, above high-tide level. Terraces, believed to be marine beaches, were found up to 205 feet, cut into glacio-fluvial deposits on the northwest side of Separation Lake and, as already indicated, outwash deposits are graded to various base levels below the marine limit. More detailed work in this area should facilitate the direct correlation between marine and glacial phases.

*Laboratory numbers: Isotopes Incorporated I-486, Geographical Branch J.D.I. 61-3S and I-487, J.D.I. 61-4S respectively.

FIGURE 18. Aerial view of the east coast of Steensby Inlet, north of the Rowley River estuary. Note the gently sloping coast and the numerous marine beaches which here rise to a height of approximately 150 feet. *Photo: J.D.I. 62-25, 24 August 1962.*

It is also significant that on the opposite side of Foxe Basin (Melville Peninsula) the marine limit is approximately 150 feet higher than on the Baffin Island side (Sim, 1960a and b). This, coupled with the Baffin Island field data, indicates that western Foxe Basin may have been ice-free while the Baffin inland ice still projected westward of the Baffin Island coast. Similarly, and at a later stage, headlands and open stretches of coast on the Baffin Island side probably became ice-free (allowing marine submergence to more than 300 feet) when the valleys and bays still contained tongues of glacier ice. This situation probably occurred in the Steensby Inlet-Separation Lake vicinity and at several localities south of the map sheet area. However, differences in altitude of the marine limit, especially where great horizontal distances are involved, as in the case of the opposite shores of Foxe Basin, may be explained by invoking normal glacio-isostatic tilt of the shore features. In the cases under review the first explanation is considered the more probable but substantiation awaits more extensive field investigation. In particular, more precise determinations are needed in northeast Melville Peninsula and in the Longstaff Bluff-Steensby Inlet sector. The possibility therefore that Foxe Basin was rapidly freed of ice with the development of a vast calving bay, once salt water penetrated Hudson Strait, must be carefully considered.

Marine shore features occur to about 300 feet above sea level at the head of Tay Sound in the northwest (Falconer, 1962b) where again they are inter-related with moraines and outwash deposits. Also, along the outer coast fronting Baffin Bay, shore features occur to probably not more than 200 feet and Goldthwait has reported outwash deposits graded to marine beaches at 180 feet in the inner fiords (Gibbs, Clyde and Clark fiords) (Goldthwait, personal communication, 1961). This evidence shows serious conflict with a marine limit of 500 feet indicated on the Isobase Map of Canada (Farrand and Gajda, 1962).

DISCUSSION

From the evidence presented, and the data plotted on the terrain analysis maps (Figures 1 and 2), a preliminary evaluation of the succession of events during deglacierization in north-central Baffin Island can be attempted.

Little can yet be said of the possible maximum extent of the last, or any preceding glaciation in the coastal mountains although the scanty data available are briefly reviewed. Similarly, no precise statement of the

significance in the glacial chronology can be attached to the Cockburn end-moraine system and the older lateral-moraine system. The over-all distribution of the end-moraine system for Baffin Island is shown in Figure 11 and its great degree of development and continuity over a distance of more than 400 miles is a major piece of evidence in the justification of the hypotheses which follow.

In northeastern Labrador-Ungava (Ives, 1960a) a fixed datum was given for the study of the deglacierization, this being the felsenmeer trim-line of the Torngat Mountains which was believed to represent the maximum stand of the last, or Koroksoak, glaciation. It was also concluded that in this area most of the highest summits were inundated at the maximum of an earlier and more extensive glaciation (Torngat). Andrews has argued that, more recently than the Koroksoak glaciation, the Saglek glaciation occurred, its upper limit being the kame terrace lateral-moraine system which in the Saglek Fiord area is approximately 350 to 400 feet lower than the felsenmeer trim-line of the Koroksoak phase (Andrews, 1961; Andrews and Matthew, 1961). These commentaries have been much influenced by the work of Dahl (Dahl, 1947, 1955, 1961, and personal communication, 1960), although it still remains to be proved conclusively that the Saglek and Koroksoak glaciations are more than glacial phases within the final glaciation of this area. These introductory remarks are inserted because of the apparent similarities between northeastern Labrador-Ungava and Baffin Island. Also, according to Dahl's theoretical considerations, the high mountains of eastern Baffin Island, which overlook deep water in Baffin Bay, provide localities which should be examined for evidence of their possible persistence as nunataks during glacial maxima (Dahl, 1947, 1955).

The general morphology of the eastern arctic rim and the apparent presence of felsenmeer on summits in the Cape Dyer and other coastal areas (Gribbon, 1961; Falconer, personal communication, 1961), would suggest that, by comparison with Labrador-Ungava, the mountain area has not been much more extensively glacierized during the last glacial maximum than it is today. Thus the maximum known level of glacial inundation is related to the high-level, lateral-moraine systems. This is called the 'Clyde phase' because Goldthwait first encountered high-level lateral moraines in Clyde Fiord (Goldthwait, personal communication, 1960). At this time all the interior of Baffin Island was undoubtedly ice-covered, and the

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inland ice probably extended across Foxe Basin to coalesce with the Keewatin mainland and Labradorean ice sheets. The Clyde phase may be tentatively correlated with the Koroksoak glaciation of the Torngat Mountains, or if a true temporal correlation is not valid, the extent of glacierization in Baffin Island during the Clyde phase was comparable with the extent of glacierization at the Koroksoak maximum in northern Labrador.

In the eastern coastal mountain areas, especially north of Buchan Gulf, in the Penny Highlands and northeast of the Penny Ice Cap, independent centres of dispersal existed, while the fiords carried outlet glaciers from the inland ice which discharged into Baffin Bay. At this phase nunatak areas almost certainly existed and Baffin Bay may have carried an extensive ice shelf. Ice thickness in the fiords is estimated at 2,000 to 3,500 feet.

The next recognizable phase is that represented by the Cockburn end-moraine system. This is termed 'Cockburn I phase' and may be the equivalent of the Saglek phase (or glaciation) in Labrador-Ungava. As already suggested, from the disposition of the moraine belt as a whole, and the individual lobate portions in particular, when the ice stood at the outermost moraines of the Cockburn system outlet glaciers reached the heads of such fiords as Cambridge, Tromso, Dexterity, Clark and Gibbs. The generalized limits of this moraine system, shown on Figures 1, 2 and 11, indicate that the interior uplands were entirely inundated with calving glaciers reaching the heads of most of the Baffin Bay fiords. Foxe Basin, or at least its eastern half, was probably also glacierized at this phase. In the coastal mountains glacierization was probably not much more extensive than it is today; with the withdrawal of the outlet glaciers from the Clyde moraines, the small fiord valley glaciers may have pushed through the lateral moraines toward tidewater, as is the situation today. Some of the mountain valley glaciers may have been as much as five miles but generally less than one mile beyond their present terminal positions. Even the Penny Ice Cap was relatively little more extensive than today, the overwhelming factor in the glacierization being the inland ice.

The term 'Cockburn I' refers specifically to a stand of the inland ice at the outermost of the Cockburn end-moraine system. Successive withdrawal from this position occurred, and fluctuations of the margin undoubtedly took place, until the northeastern margin of the inland ice had receded to the regional watershed, or just beyond it. This position marks the innermost line of end moraines and is referred to as the 'Cockburn II phase'. No precise chronological significance can be attached to this phase

so far, but at least it marks an important physical change in the processes of deglacierization. The superficial picture appears to suggest continued recession back from the heads of Clark, Gibbs and Clyde fiords to the present margin of the Barnes Ice Cap, with the progressive enlargement of ice-dammed lakes once the ice margin receded to the southwest of the regional watershed; Conn, Bieler and Generator lakes are their present day counterparts. Here another parallel with Labrador-Ungava is drawn; in this area the inland ice receded to expose the Atlantic-Ungava Bay watershed and a complicated system of glacial lakes developed, the Naskaupi glacial lakes in the George River basin (Ives, 1960b; Andrews and Matthew, 1961) and the western Torngat lakes further north (Ives, 1960a). In this sense, Baffin Island is merely a phase behind deglacierization in Labrador-Ungava; in the latter area the inland ice has completely melted (about 6,000 years ago) and the glacial lakes have drained, whereas in the former, the Barnes Ice Cap remains as a possible relic of the Pleistocene (Baird, 1952).

The situation is much more complicated than indicated above and this is why the term Cockburn II has been introduced. As the innermost of the Cockburn moraines essentially parallel the outermost, and extend for a distance of over 400 miles, simple recession of the ice margin inward to the present northeastern edge of the Barnes Ice Cap would involve a distance of less than 10 miles in places. Recession of the southern limit of the inland ice, on the other hand, at the Cockburn II phase would cover a distance of more than 150 miles before the margin had retreated to the present location of Generator Lake. Also, it is probable that the ice-divide has moved extensively since the Cockburn II phase and it seems that a much greater glacial discontinuity occurred than implied by simple, concentric recession.

The complicated process of deglacierization of the area north of the Barnes Ice Cap has been discussed in some detail in the section on the glacial drainage channels and, therefore, is not repeated here. However, once the inland ice had receded beyond the regional watershed in the north and northeast, it had attained a condition essentially similar to that of the Barnes Ice Cap today. Therefore, it seems more logical to refer to the remaining ice mass as an ice cap—the proto-Barnes Ice Cap—than an inland ice. The glacial discontinuity, previously referred to, leaves open the question that the Barnes Ice Cap may be a relic of the Pleistocene. Willow boughs, found within a few hundred yards of the northern edge of the ice

cap, apparently having been uncovered by marginal recession, may indicate previous growth of vegetation beneath the present ice cap. However, insufficient evidence prevents conclusive discussion, although these points are made to emphasize the necessity of accepting with great caution conclusions drawn concerning the mass balance of the Barnes Ice Cap when based upon a single season's observations (Baird, 1952; Orvig, 1951). Furthermore, extensive fluctuations in area, if not in volume, of ice cover have occurred during the past several centuries (Ives, 1962), and it is not inconceivable that greater fluctuations have occurred in the more distant past.

Migration of the Ice-divide

In the foregoing section the consideration of the progressive deglacierization was restricted to the northern and northeastern margins of the inland ice. Now an attempt will be made to evolve a working hypothesis for the migration of the ice-divide and to discuss concurrently the probable condition of the southwesterly and southerly margins.

It is suggested that during the Clyde phase the centre of accumulation of the inland ice lay over Foxe Basin. Regional flow across the waist of Baffin Island was then northeasterly; this movement may account for the emplacement of the limestone erratics and the formation of the linears which parallel this direction. Contemporaneous with this, Melville Peninsula probably experienced flow toward the west-northwest (Sim, 1960a) and Foxe Peninsula a southerly movement (Wilson and others 1958; Bird, 1959). During the older Cockburn phase the ice-divide probably lay close to the present Foxe Basin coast, approximately along a line from Air Force Island to Steensby Inlet, whereas by the later Cockburn phase it had migrated further toward the northeast and lay approximately 45 miles inland from Foxe Basin.* This caused a reversal of flow between the divide and Foxe Basin, to which the Separation Lake southwesterly trending forms could be accredited. Calving bays probably developed, especially in the Steensby Inlet sector and simultaneously northwestern Baffin Island developed a local centre of discharge resulting in a fan-shaped flow pattern into northern Foxe Basin.

*Erratics of granite-gneiss located in numerous places on Air Force and Prince Charles islands by members of the Dominion Observatories Gravity Survey of 1961 may well indicate a reversal of flow of some magnitude if the source area can be assumed to be Baffin Island. However, as the erratics were all discovered below the marine limit the evidence is by no means unequivocal.

During the older Cockburn phase, with the ice-divide in the vicinity of the southwest Baffin Island coast, the western limit of the inland ice may already have been withdrawing from the east coast of Melville Peninsula as the high-level sea began to penetrate through Hudson Strait and into western Foxe Basin. At least during the younger Cockburn phase the western half of Foxe Basin must have been ice-free; Melville Peninsula then experienced a marine incursion to approximately 500 feet above its present level (Sim, 1960b). Thus, rapid disintegration of the western sector of the inland ice undoubtedly occurred, although, by the time the Baffin Island outer coast had emerged from the ice, isostatic adjustment had resulted in approximately 150 feet of land uplift. This process of deglacierization is proposed to explain the great discrepancy between the marine limit on the opposite sides of the basin, but more evidence is required.

As the ice-divide shifted further northeastward and the southwest margin continued to disintegrate into salt water the entire coast became ice-free although tongues of ice remained in the deep valleys for a considerable time (the lower Rowley, Isortoq, Macdonald, Piling, for instance), an assumption based upon the greatly depressed marine limit in these localities (Sim, personal communication, 1961).

The final migration of the ice-divide to the present-day crest line of the Barnes Ice Cap must have witnessed also the complete disintegration of ice in the northwest and radical thinning of the existing ice sheet to cause lowering of the zero isotherm beneath the base of the ice cap. This latter suggestion is put forward to explain the apparent inability of the ice cap even to modify glacial flow features appearing from beneath its southwest margin. These features have already been described and indicate northeasterly flow in toward the present Barnes Ice Cap. When the inland ice was so thick that, despite low mean air temperatures, its bottom layers were at the pressure melting point, adequate erosive capacity to produce the flow features by movement over its bed presumably existed. Once a certain critical thickness (or rather thinness) was reached: the zero isotherm would pass into the ground beneath the ice cap, the bottom layers would then freeze to the bed, the differential movement would be strictly internal, and the sub-glacial flow features would be preserved.

The final phases of deglacierization are treated in detail elsewhere (Ives, 1962; Falconer, 1962a). In brief, it is believed that as much as 70 per cent of the interior uplands were covered with thin permanent ice and snow within the last 200 to 400 years and that this has successively melted off

Glacial Phase	Foxe Basin	Interior Uplands	Eastern Mountain Rim
Clyde phase (Koroksoak?) (Wisconsin Max.?)	Centre of ice dispersal in Foxe Basin with radial outflow.	Complete inundation with regional flow toward the northeast across Cockburn Land map sheet area. Ice in excess of 3,000 feet thick by projection from mountain rim.	Outlet glaciers in fiords at level of Clyde lateral moraines, calving into Baffin Bay and merging with ice shelf. Highest peaks exposed and mountain glacierization essentially local.
Cockburn I phase (Saglek phase?) (Mankato?) 10,000 B.P.	Ice-divide over, or close to, Baffin Island southwest coast.	Complete inundation with regional flow to northeast. Northeast margin of inland ice at outer Cockburn end moraines.	Outlet glaciers calving into heads of fiords only. Mountain glacierization slightly expanded as valley glaciers descend to breach Clyde moraines.
Cockburn II phase (post-Saglek?) (post-Mankato?) (Cochraine?) Boreal 7,000 B.P.	Ice-divide 40 miles NE of Foxe Basin coast. Maximum marine submergence of Melville Pen. Baffin ice still entering Foxe Basin on a broad front.	Ice-divide over SW part of uplands with NE flow across present site of Barnes Ice Cap with margin against inner Cockburn moraines. Later in this phase, with rapid thinning, outer Foxe Basin coast ice-free and inundated by sea to 315 – 340 feet. Flow to SW from Borden centre across Steensby Inlet. Isortoq-Separation moraines constructed in southwest.	Mountain glacierization little more extensive than today. Outwash laid down by inland ice into heads of fiords to marine base level 180 ft. higher than today. Bruce, Buchan, Padloping, Penny and Hall ice caps virtually detached and independent of inland ice.
Atlantic 5,000 B.P.	Foxe Basin coast ice-free with glacier ice calving into inner bays and fiords. Sea level approx. 100 – 250 ft. above present.	Rapid thinning of inland ice. Recession of margin across regional watershed. Glacial lake and kame terrace phases. Migration of divide toward northeast and oscillations of SW margin causing southwest end-moraine construction.	Inland ice withdrawn across watershed from mountain foothills. Overflow of lakes terrace outwash deposits in valleys leading to fiords. Mountain glaciers expanded; totally separated from inland ice. Rowley River-Isortoq watershed ice-free toward close of this phase.

Sub-boreal 3,000 B.P.	Ice tongues disintegrate in valleys leading to Basin. Sea level falls to less than 100 ft. above present.	Proto-Barnes Ice Cap separated from stagnating ice relics in basins of Rowley and Pilik rivers to northwest. Complex system of lateral lakes in upper Isortoq River basin with overflow to west. Ultimate disintegration of ice in main valley and recession to within close to existing Barnes Ice Cap margins.	Minor recession of mountain glaciers from outermost moraines. Thinning of ice caps and rise in firn line to summits.
Sub-Atlantic 1,000 B.P.	Sea level continues to fall.	Limited advance of Barnes Ice Cap margin to block middle Isortoq Valley. Damming up of large lake in upper Isortoq Valley. Extension of thin snow and ice patches on uplands.	Minor fluctuation of local glaciers. Extension of thin plateau ice caps.
Recent cool		Extension of thin ice patches and permanent snow to cover 70% of interior uplands. Thinning and recession of ice cap and patches toward close of this phase – drainage of main ice-dammed lake in upper Isortoq.	Minor fluctuation of local glaciers. Extension of thin plateau ice caps. Possible maximum or secondary maximum stand of glaciers.
99–0 B.P.		Gradual reduction in area of permanent ice and snow patches to only 2% coverage. Further recession of ice cap margins 2 to 10 miles in places; stability in others.	Thinning of glacier tongues and recession ½ to 5 miles from outermost moraines.

leaving an approximate present-day coverage of 2 per cent (excluding the Barnes Ice Cap). Similarly, sections of the ice cap extended to 10 miles beyond its present position within the same period and dammed up a lake, 50 miles in extent and up to 700 feet deep, in the upper Isortoq valley. Marginal recession continues and the budgetary state may be far less healthy than Baird indicated (Baird, 1952). On the other hand, both Ward and Goldthwait cite evidence for local advance or prolonged still-stand along the northeast margins (Ward, 1953; Goldthwait, 1951).

CONCLUSIONS

Several working hypotheses evolve from the foregoing discussion and it is hoped that these will form a framework within which the future field work can be organized. Perhaps the most important concept is that the interior uplands, rather than the eastern arctic mountain rim, have been the more important as a locus of glacierization and glaciation. Especially during the deglacierization phase of the last glaciation it is evident that, initially, a major inland ice, discharging northeastward through the mountain rim, overwhelmingly predominated over the mountain glacierization. Successively later phases in the deglacierization saw the gradual reduction of the inland ice, although it seems unlikely that the mountain ice caps and glaciers were ever appreciably more extensive than today. From this argument it is postulated that, as in the case of Labrador-Ungava, the interior uplands experienced more extensive glacierization at the onset of each glacial stage than the eastern mountains. Thus the original concept of initiation of glaciation on the coastal mountains (Flint, 1943 and 1953) is rejected in favor of the concept of "instantaneous glacierization across wide areas of the plateau" *(Ives, 1957), a point of view which contrasts with the recent interpretation of glacial features in southern Baffin Island by Bird (1958).

The remaining major conclusions are incorporated within the preceding chronological table. Figures 19 to 22 are a graphic presentation of the working hypotheses using the existing data and are intended as a basis for discussion and criticism. It is emphasized, however, that subjective correlation of glacial phases from one geomorphic province to another has been freely used and both the table and figures should be regarded as tentative.

*Interior uplands in the case of Baffin Island.

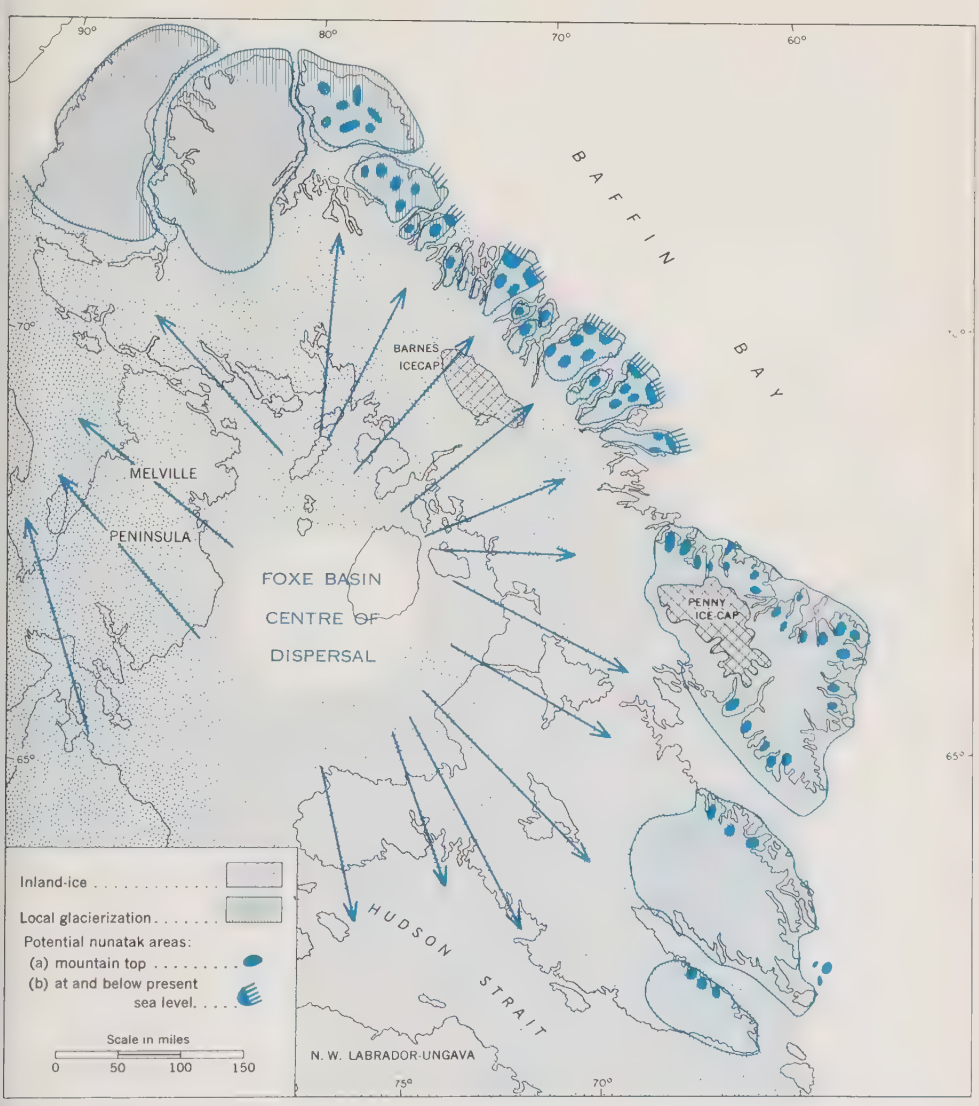

FIGURE 19. This and Figures 20, 21, and 22 are a graphic and hypothetical interpretation of the existing data. They are intended as a working model for future testing in the field. Undoubtedly many modifications and alterations will be made. Figure 19 shows the estimated conditions of maximum glacierization with coastal and mountain nunataks remaining ice-free and the centre of ice dispersal over Foxe Basin. No chronological significance is attached to this representation.

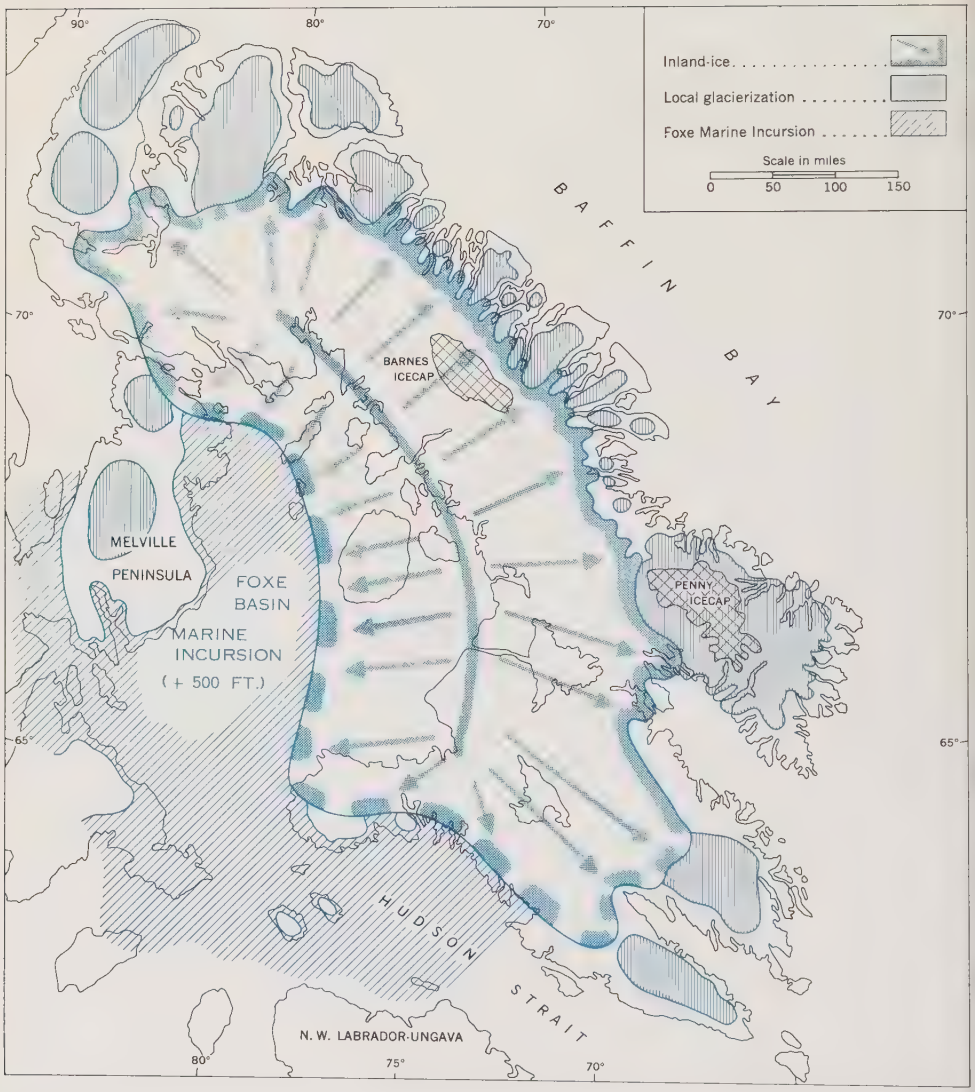

FIGURE 20. A late-glacial phase shown cartographically and referred to in the text as Cockburn I. Strict contemporaneity is not claimed throughout the sketch. A radiocarbon date of 10,450 ± 250 years has been obtained from marine molluscs collected at 281 ft. above sea level from south Hudson Strait (Isotopes Inc. I-488/G.B.—J.D.I. 61-6S, collected by B. Matthews) whereas the oldest date so far obtained within Foxe Basin is 6,725 ± 250 years at 290 feet north of Baird Peninsula (I-406/G.B.—V.W.S. 61-1S collected by Dr. V. W. Sim). However, the Cockburn outer moraines may be much older than 10,450 years.

FIGURE 21. Cartographic representation of the Cockburn II late-glacial phase. If any degree of contemporaneity has been achieved, the date of 6,725 ± 250 years for marine molluscs collected from a height of 290 feet (cf caption to Figure 20) should be significant.

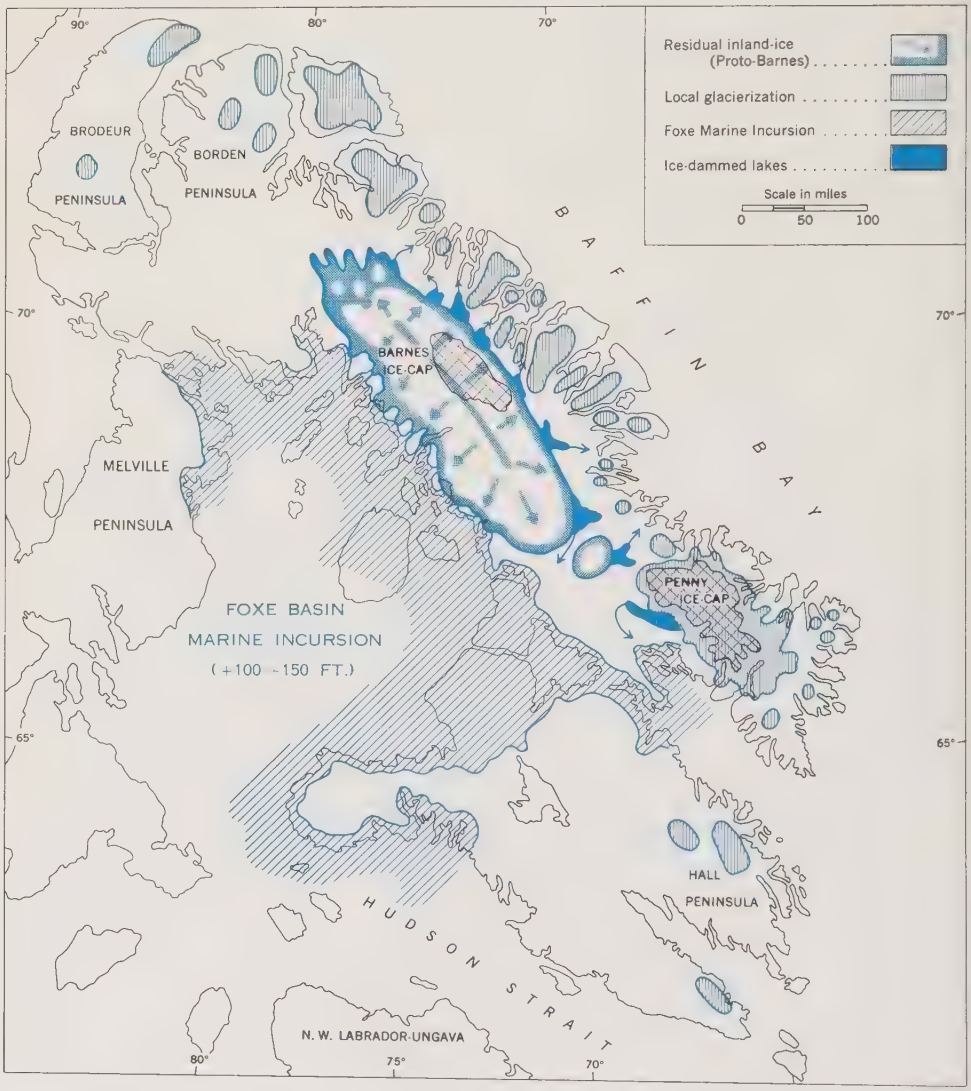

FIGURE 22. Cartographic representation of the proto-Barnes late-glacial phase. The 100- to 150-ft. sea level and the interpreted margin of the ice cap may not have been occupied simultaneously although a radiocarbon age of 4,700 ± 210 years for marine molluscs found at 70 feet above sea level in Steensby Inlet may be significant (I-487/G.B.—J.D.I. 61-4S). The large pro-glacial lakes have been plotted schematically on the basis of air photograph interpretation of abandoned shorelines.

ACKNOWLEDGMENTS

Thanks are extended to Dr. R. P. Goldthwait for many stimulating discussions and for making available unpublished data collected during his own pioneer work in the eastern sector of the map area. Thanks are also due to Dr. W. H. Ward for valuable discussion of aspects of the field work. P. L. Hill acted as field assistant and A. C. Hamilton, leader of the Dominion Observatories 1961 Baffin Island gravity survey rendered invaluable practical assistance in the field. Several members of the Geographical Branch staff have contributed to the evaluation of the field data, in particular Dr. V. W. Sim, whose work on the Foxe Basin North map sheet is a parallel study to that described here. Finally, the staff of the Distant Early Warning Line in western Baffin Island provided an admirable field base and rendered great material assistance throughout the summer and thanks are due to the Federal Electric Corporation.

References

Andrews, J. T.
1961: The glacial geomorphology of the northern Nain-Okak section of Labrador. Unpublished M.Sc. thesis presented to *McGill University*, 279 p.

Andrews, J. T. and Matthew, E. M.
1961: Geomorphological studies in northeastern Labrador-Ungava. Geog. Paper No. 29. *Geographical Branch*, Ottawa.

Baird, P. D.
1952: Method of nourishment of the Barnes Ice Cap. *J. Glaciol.*, vol. 2, no. 11, 2-9.

Baird, P. D. and others.
1950: Baffin Island Expedition, 1950. *Arctic*, vol. 3, no. 3, 131-149.

Bergdahl, A.
1959: Glacifluvial estuaries on the Narke Plain. *Svensk Geogr. Arsbŏk*, 35. 67-71.

Beschel, R. E.
1961: Dating rock surfaces by lichen growth and its application to glaciology and physiography (Lichenometry). *Geology of the Arctic* (ed. by G. O. Raasch) University of Toronto Press, vol. 2, 1044-1062.

Bird, J. B.
1958: A report on the physical environment of southern Baffin Island, N.W.T., U.S.A.F., Project RAND, *Research Memorandum RM-2362*, mimeo. McGill University, Montreal, 375 p.

Blackadar, R. G.
1958: Patterns resulting from glacier movements north of Foxe Basin, N.W.T. *Arctic*, vol. 11, no. 3, 156-165.

Dahl, E.
1947: On different types of unglaciated areas during the ice ages, and their significance to phytogeography. *The New Phytologist*, vol. 45, no. 2, 225-242.
1955: Biogeographic and geologic indications of unglaciated areas in Scandinavia during the ice ages. *Geol. Soc. Am. Bull.*, vol. 66, 1499-1519.

Falconer, G.
1962a: Inventory of Canadian glaciers, Pt. 1, northern Baffin and Bylot islands, N.W.T. Geog. Paper No. 33. *Geographical Branch*, Ottawa.
1962b: Unpublished report on field work in north-central Baffin Island. *Geographical Branch*, Ottawa.

Farrand, W. R. and Gajda, R. T.
1962: Isobases on the Wisconsin marine limit in Canada. *Geog. Bull.*, 17. Ottawa. 5-22.

Flint, R. T.
1943: Growth of the North American ice sheet during the Wisconsin Age. *Geol. Soc. Am. Bull.*, vol. 54, 325-362.
1953: Probable Wisconsin sub-stages and late-Wisconsin events in northeastern United States and southeastern Canada. *Geol. Soc. Am. Bull.*, vol. 64, 897-920.

Goldthwait, R. P.
1950: Geomorphology (*in*: Baffin Island Expedition, 1950: a preliminary report, by P. D. Baird and others). *Arctic*, vol. 3, no. 3, 139-141.
1951: Development of end moraines in east-central Baffin Island. *J. Geol.*, vol. 59, 567-577.

Gribbon, P. W. F.
1961: Report on Bagnall Fiord, Baffin Island, N.W.T. Unpublished manuscript, mimeo, held in Geographical Branch library, Ottawa.

Hoppe, Gunnar.
1957: Problems of glacial morphology and the ice age. *Geog. Annal.*, vol. 39, no. 1, 1-18.
1960: Glacial morphology and the inland ice recession in northern Sweden. *Geog. Annal.*, vol. 41, no. 4, 193-212.

Ives, J. D.
1957: Glaciation of the Torngat Mountains, Northern Labrador. *Arctic*, vol. 10, no. 2, 67-87.
1959: Glacial drainage channels as indicators of late-glacial conditions in Labrador-Ungava: A discussion. *Cahiers de Géog. de Qué.*, 3ième Ann., no. 5, 57-72.
1960a: The deglaciation of Labrador-Ungava: An outline. *Cahiers de Géog. de Qué.*, vol. IV, no 8, 324-343.
1960b: Former ice-dammed lakes and deglaciation of the middle reaches of the George River, Labrador-Ungava. *Geog. Bull.*, no. 14, 44-70.
1962: Indications of recent extensive glacierization in north-central Baffin Island, N.W.T. *J. Glaciol.*, vol. 4, no. 32, 197-205.
1964: The terrace forms of the upper Isortoq River, north-central Baffin Island—a study of the deglacierization process. *Geog. Bull.* (in press).

Løken, O. H.
1962a: Deglaciation and postglacial emergence of northernmost Labrador. Unpublished Ph.D. thesis, *McGill University*, Montreal.
1962b: The late-glacial and postglacial emergence and the deglaciation of northernmost Labrador. *Geog. Bull.*, no. 17, 23-56.

Mannerfelt, C. M: son:
1945: Några glacialmorfogiska formelement. *Geog. Annal.*, Arg. XXXIII, Heft 3-4, 166-209.

Orvig, S.
1951: The climate of the ablation period of the Barnes Ice Cap in 1950. *Geog. Annal.*, Arg. XXXIII, Heft 3-4, 166-209.

Sim, V. W.
1960a: A preliminary account of late "Wisconsin" glaciation in Melville Peninsula, N.W.T. *Can. Geogr.*, no. 17, 21-34.
1960b: Maximum post-glacial marine submergence in northern Melville Peninsula, N.W.T. *Arctic*, vol. 13, no. 3, 178-193.

Ward, W. H.
1952: The physics of deglaciation of central Baffin Island. *J. Glaciol.*, vol. 2, no. 11, 9-22.
1953: Comments on Dr. Orvig's paper. *J. Glaciol.*, vol. 2, no. 14, 247-248.

Wilson, J. T. and others.
1958: Glacial map of Canada. *Geol. Assoc. Can.*, Toronto.

CROSS-VALLEY MORAINES OF THE RIMROCK AND ISORTOQ RIVER VALLEYS, BAFFIN ISLAND N.W.T.—

A descriptive analysis

J. T. Andrews

ABSTRACT: Cross-valley moraines of north-central Baffin Island, N.W.T., particularly those of the Rimrock and Isortoq river valleys, are described in detail. The relation of the moraines to former glacial lake shorelines is discussed, and five possible hypotheses for their formation are proposed.

RÉSUMÉ—L'auteur décrit avec soin des moraines transversales qu'on trouve dans le Nord de la partie centrale de l'île Baffin (T. N.-O.), surtout celles des vallées des rivières Rimrock et Isortoq. Il étudie les rapports qui existent entre ces moraines et les anciennes lignes de rivage de lacs glaciaires et formule cinq hypothèses sur la genèse des moraines.

INTRODUCTION

The program of air photograph interpretation and field research in north-central Baffin Island, N.W.T., initiated by the Geographical Branch in 1961,* has already led to a considerable increase in knowledge of this hitherto geographically unexplored area. The interpretation and plotting of glacial erosional and depositional forms has led to a realization that this region, and in particular the area around the present margin of the Barnes Ice Cap, is a natural laboratory for the study of glacial-morphological processes. The importance of studies originating from these observations cannot be sufficiently stressed. Glacial geomorphology as a branch of geography has been primarily concerned with erosion and deposition under temperate glacial conditions, with the ice mass at the pressure melting point. Glacial forms occurring in arctic areas have been attributed to the same set of processes as those occurring under the vastly different glaciological conditions of more southerly latitudes, and rarely has any attempt been made to examine the structure and composition of these forms. It is possible, even probable, that some glacial features have a like origin regardless of glaciological conditions, but it is also possible that forms, superficially similar in external characteristics, differ in the mechanics of their formation.

This study is a detailed description of the cross-valley moraines of north-central Baffin Island, glacial depositional features that have not been adequately described or examined previously. They were initially observed on air photographs as a series of cross-valley ridges located around

*See paper by Ives and Andrews in this Bulletin.

MS submitted May 1962.

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the margins of the Barnes Ice Cap (Figure 3). During the summer of 1961 a three-man party from the Geographical Branch examined in detail the glacial forms in a small area some 25 miles north of the ice cap (Figure 1). From the outset it was realized that an adequate knowledge of the deglacierization of the area could be gained from *a.* a study of certain lateral, marginal, and frontal forms, and *b.* an examination of the cross-valley moraines. It should be noted that this latter term is used only in a descriptive sense, and it is not intended that any mechanism of formation be presupposed. Ives (1964) investigated the terrace forms, and the writer dealt primarily with the cross-valley moraines. The chief aim of the writer's field survey was to furnish material for a detailed description of the cross-valley moraines, and to provide data for laboratory and statistical manipulation.

The information thus gained during the summer can be broken down naturally into two separate component parts, both distinct entities and able to stand as separate studies, but at the same time both contributing toward an understanding of the origin of the cross-valley moraines. This paper is concerned essentially with describing the cross-valley moraines and associated deposits; the description is mainly detailed and is intended to serve as a guide in the eventuality that similar moraines are found elsewhere.

Fraser (1962, personal communication) has observed cross-valley moraines on Boothia Peninsula below the marine limit. Lee (1960) has observed what appears to be, at least superficially, similar forms in the Great Whale River area above the marine limit, and there appears to be some resemblance in form between the cross-valley moraines of Baffin Island and the 'Rogen' type moraine in Sweden (Lundqvist, 1937; Hoppe, 1952). It is again emphasized that although all these glacial forms appear superficially alike, a conclusion that they are similar would be warranted only after a careful examination of the internal structure of the moraines.

In this paper, five working hypotheses of origin are advanced. A second paper (Andrews, 1963), dealing with the quantitative analysis of certain aspects of cross-valley moraines, examines the hypotheses in detail and reaches certain tentative conclusions on their origin; the results of till-fabric analysis on the moraines are discussed, and the sedimentary characteristics of cross-valley moraines are analyzed.

FIGURE 1. Location map of field areas.

Location of the Cross-Valley Moraines

The initial air photograph interpretation phase of the Cockburn Land 1:500,000 map sheet (Figure 1, Ives and Andrews, in pocket) revealed that in addition to the normal glacial forms, such as end moraines and glacial drainage channels, some unusual forms existed. It became apparent that a discussion of the deglacierization of the area would involve the introduction of new concepts, and a reappraisal of the now classical concept of the deglacierization of an area by the downwasting of the ice mass, at least as applied to this single arctic area.

In many of the valleys around the margin of the Barnes Ice Cap transverse ridges literally cover the valley floor and sides. Goldthwait (1951a) was the first to describe these ridges, calling them 'sub-lacustrine moraines'. No detailed observations, however, were included, nor was any

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argument advanced on their origin. The detailed air photograph interpretation (Ives and Andrews, 1963) of the Cockburn Land sheet, and a rather more cursory examination of the areas to the north and south, has extended the known occurrence of the cross-valley moraines, and it has also led to a more exact definition of the glaciological conditions that must, it seems, exist before cross-valley moraines are formed.

No cross-valley moraines have been seen on the western parts of the map area, though on the west coast of Steensby Inlet there is a belt of minor moraines similar to those described by Lee (1960) and Craig (1961). In the north, cross-valley moraines have been traced on the floor of the Pilik valley, and some of the north bank tributaries of this river (Figure 2). The moraines are virtually absent from the Rowley River system, except for a small area in the upper south bank tributary. The cross-valley moraines are best developed in the Isortoq valley, upstream from the Lewis Glacier. In the upper section of the valley, a transition occurs between end and lateral moraines and the cross-valley moraines as the regional watershed is crossed. The upper Striding valley shows a very good degree of development of the moraines. Other examples occur as partially submerged ridges in tributary bays of Conn and Bieler lakes. The main shores of these lakes are devoid of moraines.

The virtual absence of the cross-valley moraines in the Pilik and Rowley valleys, two major west-flowing rivers, is the more noteworthy because of their considerable development in the Isortoq drainage system; this absence possibly reflects a change in conditions during deglacierization.

The moraines can be traced southward along the eastern margin of the Barnes Ice Cap to the Clyde River. They are especially prominent on the sides of Generator Lake, in a south bank tributary of the Sam Ford valley, and in tributaries of the Clyde River.

South of these localities the air photograph interpretation has been of a reconnaissance nature, and was undertaken with the aim of delimiting the areal extent of the Cockburn end moraines and the cross-valley moraines. The whole of Baffin Island was examined during this survey. Cross-valley moraines were noted in nearly all the upper valleys of westward-flowing streams (Figure 2), and they were eventually traced to within 30 miles of the northwestern margin of the Penny Ice Cap. A hiatus of 200 miles in moraine occurrence was observed between this latter point and the west-flowing tributaries of the McKeand River, which flows into Cumberland Sound.

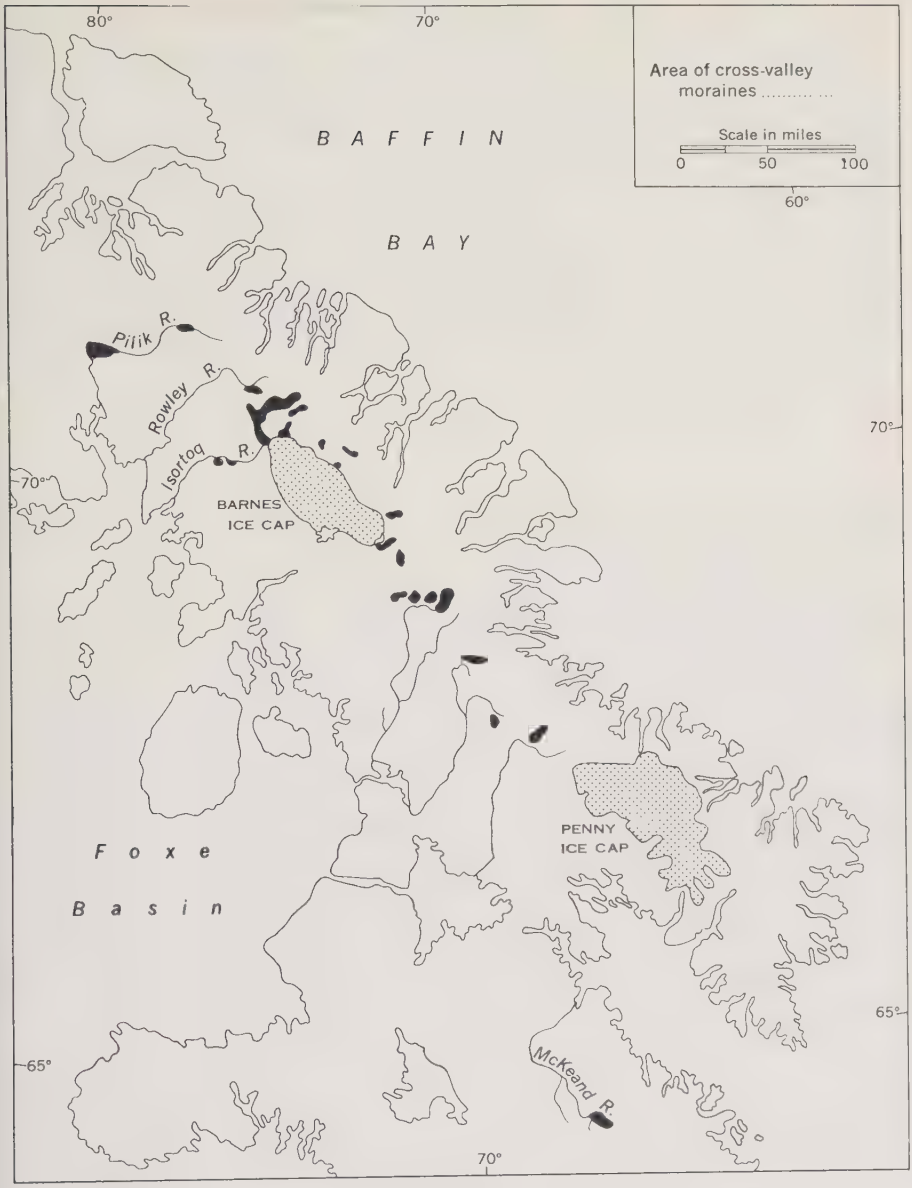

FIGURE 2. General location map of cross-valley moraines in Baffin Island.

Air photograph interpretation indicates that a strong correlation existed between the location of the cross-valley moraines and the areas characterized by abandoned high-level shorelines. From these shorelines it is inferred that former glacial lakes had been ponded between the main watershed and the westward-retreating late-Pleistocene ice cap. In fact, in

FIGURE 3. Aerial view of typical cross-valley moraines situated several miles north of the Barnes Ice Cap. The larger ridges must be between 80 and 100 feet high. The ice cap can be seen in the top right lying south-southwest of the camera station. *Photo: J.D.I. 62-4, 25 August 1962.*

all cases where cross-valley moraines were located, elevated shorelines were also observed. The location of the cross-valley moraines thus forms a discontinuous band, running from the Pilik River in the north, to the McKeand River in the south, a distance of 650 miles. The moraines are situated east of a former ice-divide and west of the major watershed. In a few instances cross-valley moraines lie to the west of the ice-divide, and, in the lower Isortoq valley, they have been formed in tributary valleys where the evidence suggests that a lake was ponded against the main trunk glacier.

The cross-valley moraines are thus intimately associated with former glacial lakes, and the evidence of the shorelines, plus the slope of glacial drainage channels and other indicators of glacial directional movement, suggests that only when a glacier or ice cap is retreating down a regional or local slope and into water are the necessary conditions for the formation of the moraines realized. The moraines are restricted to the interior upland physiographic region, a region characterized by broadly convex hills rising from a gently undulating upland surface. Relief is 1,000 feet or less. The relief conditions precluded the formation of long tongues of ice in the main valleys; instead, it would appear that the margin of the late-Pleistocene ice cap was analogous to the eastern edge of the present Barnes Ice Cap. The retreat of the ice cap into Conn and Bieler lakes (Figure 4) epitomizes the conditions under which the glacial lakes were formed, and if one can judge from Generator Lake, the way in which the cross-valley moraines were created. The existence today of glacial lakes around the Barnes Ice Cap is especially interesting because of current work in Scandinavia

(Holdar, 1952) and Britain (Sissons, 1958); in both areas, early hypotheses of deglacierization demanded the existence of glacial lakes, but present workers are refuting these ideas.

The seeming probability that the cross-valley moraines are sub-lacustrine forms suggests that there is a genetic relationship between these features and the sub-marine De Geer moraines (Hoppe, 1959), the estuarine ridges (Bergdahl, 1953, 1959, 1961), and the minor moraines (Lee, 1960;

FIGURE 4. Conn Lake with calving bay of Barnes Ice Cap. Note: (a) crevasse pattern near the margin of the ice cap, (b) that several streams disappear down crevasses at some distance from ice cliff, and (c) that pattern of retreat has left ice well in advance of centre of calving bay. A similar, but smaller calving bay can be seen in the smaller lake at the extreme top margin. *Photo: RCAF vertical No. A-16293-103, 27 August 1958.*

Craig, 1961). This suggestion requires that precise quantitative studies be performed on the internal structure of these various forms; moreover, these studies should be presented in such a way that the data is accessible to other workers. A recognition of similar and dissimilar characteristics would play a vital part in the understanding of certain glacial depositional processes. In regions where ice is calving into a lake, local conditions of ground temperature and ice basal temperature might be similar to those in more temperate regions.

The relationship between the cross-valley moraines and the former lake shorelines is not always clear. In many instances there are a number of abandoned shorelines, and without detailed field investigations it is impossible to say whether the moraines actually crossed a shoreline while they were being formed, or whether those instances where shorelines obviously post-date the moraines are simply due to wave action in a glacial lake, both younger and lower than the shoreline existing at the time of moraine formation. In many instances, the latter hypothesis is an adequate explanation, but in other cases, as on the south side of Bieler Lake, the cross-valley moraines cross the single, high-level shoreline.

Because of the obvious relationship between glacial lakes (it should be noted that not all former glacial lakes are associated with cross-valley moraines) and the cross-valley moraines, their distribution pattern should shed considerable light on the problem of locating late-glacial ice-divides. A change in glacial features, such as that occurring at the junction of the Isortoq and Lewis rivers where cross-valley moraines and glacial lake shorelines are superseded by glacial drainage channels and lateral moraines, denotes a radical alteration in the relationship between the local ice-divide and natural drainage direction.

The air photograph interpretation has revealed an immediate and obviously crucial relationship between glacial lakes and cross-valley moraines, which, although it does not answer the question of how the moraines were formed, does provide a basic point of departure from which to work.

CROSS-VALLEY MORAINES OF THE RIMROCK RIVER

This section provides a detailed descriptive analysis of the cross-valley moraines in the Rimrock and Isortoq valleys (Figure 1); it is based on the observations of the 1961 field survey.

FIGURE 5. Panorama looking southwestwards across the upper Isortoq valley showing exceptionally well developed cross-valley moraines. Central kames can be seen by the river towards the left and the shoreline of glacial lake Lewis coincides with the line of small snow patches immediately above the kames. Two small perched deltas, coincident with a lower lake level, can be seen at the extreme left and right respectively. *Photo: J.D.I. 61-232, 21 July 1961.*

Physical Setting

The broad physiographic regions of north-central Baffin Island have already been outlined (Ives and Andrews, this Bulletin). The area lying north of the Barnes Ice Cap presents a landscape of moderate relief, with wide, open valleys, and gently convex hills rising above a rolling upland surface approximately 2,000 feet above sea level in the field area. Maximum relief is about 1,000 feet, but this is generally spread over a considerable linear distance. The Rimrock valley is broad and open, and drains east and then south to the Isortoq River. Downstream from the lake outlet is a series of poorly developed cross-valley moraines, seemingly formed entirely of large angular boulders. Farther downstream, for a distance of approximately 4 miles, a series of small flat-topped, conical kames (Holmes, 1947) occupies the centre of the valley (Figure 5). On either side, the ground moraine, consisting of angular blocks 2 to 5 feet in diameter, forms a network of intersecting ridges and enclosed hollows. Two miles south of the upper bend these deposits are replaced by linear, transverse ridges that superficially appear as rather simple forms, but upon closer inspection are revealed as being extremely complex (Figures 6 and 7). Deposits of sands and gravels, generally rising above the crest of the moraines, in places straddle them (Figure 8) and in other places appear as discrete deposits. Hereafter these stratified features are referred to as the *central kames.* Two miles farther down valley the cross-valley moraines become less pronounced, and the most striking feature is a belt of coalescing central kames which traverse the valley at right angles to the moraines (Figure 7). Two massive moraines, noticeably convex toward the south, extend across the valley. There is a dearth of glacial features between this point and the junction with the Isortoq River, though very faint ridges 1 to 2 feet high can be discerned in a west-bank tributary, both on the ground and on the air photographs. They are associated with a series of small kames.

Direction of Ice Movement

Roches moutonnées, glacial lineations, and the disposition of glacial grooves and striations on ice-molded bedrock indicate that at one time the regional ice movement was directed toward the northeast, with the orientation of striations varying from N 25° E to N 50° E. During this period the ice moved obliquely across the Rimrock River valley from a centre of dispersal somewhere to the southwest of the area. Striations near river level show that even the basal layers of the ice were affected and that topography played little part in determining the direction of flow. Three

exposures suggest, however, that these conditions did not prevail during the final stages of the deglacierization, for striations trending N 10° W were observed to truncate northeasterly trending striations, implying that the former were the younger of the two sets. There is thus evidence for a late-glacial ice movement directed north along the valley. This movement probably occurred after the thinning of the ice, with the concomitant result that topography increased in importance as a controlling agent on the direction of ice movement. However, it further suggests that the centre of dispersion of the ice had shifted from a position southwest of the area to a more southerly location.

Description of the Cross-Valley Moraines

A description, however detailed, has certain inherent disadvantages because of the complex pattern of the moraines and the difficulty of generalization. Most of the aspects dealt with in this paper, such as slope, angle, height, width, angle of junction with other ridges etc., are susceptible to greater quantitative treatment than is accorded to them in this paper. It is recognized nevertheless, that information of this nature is needed, and it will be collected in the future surveys. The main reasons for the collection of these data would be the setting up of confidence limits, and the analysis of recurring trends and patterns. To date only the internal composition and structure of the moraines has been dealt with quantitatively.

In the middle and lower Rimrock River valley the moraines are generally orientated at right angles to the last recorded direction of ice movement (Figure 7). Certain moraines, noticeably MR I and MR II* are noticeably lobate and, being convex toward the former direction of ice movement, are thus radically different in this respect from normal end moraines. In detail, however, the moraines show no rigid organization; they are gently sinuous, or else consist of small sections slightly offset from each other. Many of the smaller intervening ridges are not orientated at right angles to the last ice movement, and may even be parallel to it.

The height of the moraines varies within wide limits, both along any single moraine, and from ridge to ridge. There is, however, a certain discernible pattern: the cross-valley moraines commence on the hillside as small ridges approximately 2 to 3 feet high. They increase in height toward the valley floor and reach a maximum height of between 15 to 45 feet. A point of maximum height is reached on either side of the central axis of the

*The notation MR I, R I, II, etc., is used to locate the individual moraines (Figure 7).

valley; beyond that point the moraines decline progressively toward the river. By the time the bank of the river is reached they are usually less than 10 feet high. There are exceptions: RV III is 30 feet high where it is breached by the river, and MR I and MR II are at least 40 feet high in a

FIGURE 6. Cross-valley moraines of the Rimrock valley. Note the areas of sand deposits running at right angles to the moraines and forming central kames, and the many variations in form that occur along the axis of individual moraines. Glacial lake Lewis is clearly demarcated by the change in color above and below the shoreline. *Photo: part of RCAF vertical No. A-16293-25, 27 August 1958.*

FIGURE 7. Map of Rimrock area; compare with Figure 6.

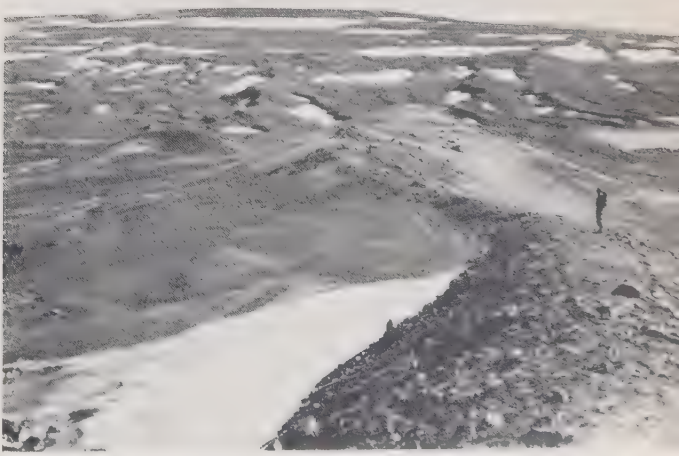

FIGURE 8. Zone of contact between cross-valley moraines and central kames. Note coarse boulder cover of moraine lenses out onto the kame. *Photo: J.T.A. 61-4-3, 6 July 1961.*

FIGURE 9. North face on distal slope of cross-valley moraine in Rimrock valley. Slope 34° to 36°, littered with boulders. *Photo J.T.A. 61-3-7, 5 July 1961.*

similar situation. In most instances they are insignificant near the river, but the location of rapids, leading directly across the river from a moraine suggests that at one time they were continuous cross-valley features. In some localities the moraines are only noticeable during the strong evening light, presenting a pattern similar to a well-ploughed field.

No attempt was made to measure the distance between the separate moraines over the entire field area, though selected measurements were made. These indicated an interval of approximately 150 to 200 ft., although in areas where the moraines have a small amplitude this figure is reduced to between 20 to 40 feet. In the middle section of the valley the moraine ridges appear to fall into four main groups, with a series of high, distinct features being succeeded by a number of smaller ones, which in turn are followed by another group of the more massive ridges. Whether any pattern exists in the spacing of the ridges will only be seen after a detailed, quantitative study.

One of the most striking features of the moraines is the asymmetry of their cross profile, numerous measurements revealing that the distal slope, in this case the north-facing slope, is inclined at 30° to 40° (Figure 9) while the proximal slope varies between 17° and 25° (Figure 10). The asymmetry was even observed on the very small moraines. It might well be argued

that the steeper distal slope is not a primary characteristic, but is a result of secondary modifications due to periglacial activity. Late-lying snowbanks occupy many of the north-facing slopes but disappear early on the southern slopes, and thus this argument must be examined carefully. It is submitted, however, that the asymmetry is a result of the original depositional process. This thesis is advanced after a careful consideration of the evidence on both slopes. Both the south- and north-facing slopes illustrate certain aspects of periglacial activity, with minor flow features located mainly on the northern slopes. These slopes, however, meet the ground moraine with a very sharp angle and there is very little evidence of any slump material at their base. The till-fabric analysis adds further support for the proposal that the asymmetry is a primary feature though this is discussed in a later paper (Andrews, 1963). The asymmetry of the moraines, therefore, is considered an inherent characteristic.

Numerous exposures were examined, and many pits excavated to provide a true estimate of the composition of both the cross-valley moraines and the central kames. This aspect will be dealt with in detail in the later study, but results show that the cross-valley moraines are formed of a sandy till, and that the central kames are formed of bedded sands and gravels.

The surficial cover of the moraines varies both as regards the percentage area effectively masked and the nature of the surficial deposits.

FIGURE 10. South-facing, or proximal slope of cross-valley moraine in Rimrock valley. Compare with Figure 9 and note difference in slope. *Photo: J.T.A. 61-2-2, 3 July 1961.*

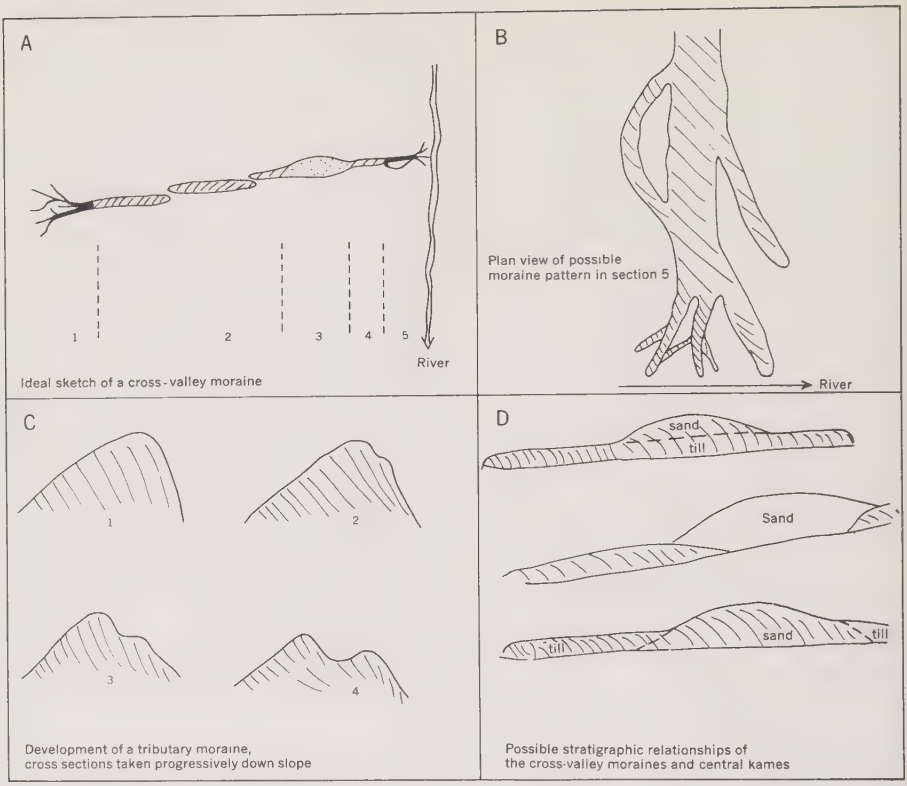

FIGURE 11. Sketches of certain aspects of cross-valley moraines.

In their upper sections the inner core of the moraines is entirely masked by a mantle of large angular boulders with diameters of 2 to 4 feet. The boulder cover is not restricted to the moraines; the intervening areas are similarly covered. In places the moraines might be composed entirely of this material. Many of the boulders rest in unstable, and even perched positions, and some boulders appear to have fallen into the moraine crest. The angularity of the material is very marked, and it appears that this material has been little affected by transportation. In places it is possible to map the underlying bedrock geology by the occurrence of a particular rock type in the ground moraine.

The area between the moraines covered by large boulders decreases toward the centre of the valley. This might be due in part to burial of boulders under a layer of clay. The moraines themselves, however, still have a marked boulder cover, involving 30 to 70 per cent of the surface area (Figures 9 and 10). The morphometry of the boulders is still rather

angular, despite an increase in the roundness factor, although the measurements on the roundness and area covered need to be defined more rigorously. During the numerous excavations into the moraines, large boulders were encountered at depth, in some cases making further excavation very laborious. In most cases, however, boulder cover is predominantly surficial, and is not caused by the removal of fines from the moraine crest and sides; deposition of most of the boulders therefore post-dates that of the moraine formation.

Experience in the field indicated that it is very difficult to generalize on the distinctive traits of the cross-valley moraines. Nevertheless, certain facets of development are sufficiently repeated to justify some comment, and this allows them to be divided into four main units from their commencement on the hillside to the centre of the valley (Figure 11). They begin as small ridges and gradually emerge from the maze of boulders which are found at the higher elevations. Several ridges, with a fan-shaped gathering ground (Figure 11A) will then lead to one main ridge, noticeably larger than any of its component ridges, which can be followed down the hillside, sometimes as a single continuous ridge, but most often presenting a series of sharply terminated ridges, continuing in a slightly offset position to each other (Figure 11A 2). In the third section the moraine changes its form from a steep, rather narrow ridge with a surficial cover of angular boulders, to a distinctly higher central kame composed of bedded sands and gravels with angular and rounded boulders littered over the surface (Figure 8). In many instances there is no apparent morphological break between the moraine and the central kame except for a distinct increase in height, though in other places the central kames stand as discrete units, obviously unrelated to any one particular cross-valley moraine. The central kame section is followed by a moraine development comparable to the second unit (Figure 11A 2). As the moraines approach the river, they often lose their individual form, with distributary ridges branching from the main ridge (Figure 12), and occasionally rejoining it (Figure 11B). The moraines are generally quite small near the river, and often terminate in a maze of ridges running in all directions. However, as previously mentioned, several of the moraines are massive in their lower portions, and are dissected by the river. There is no doubt that at the time of formation these features extended across the valley without a break. Where they become very low near the river, the presence of rapids also suggests that these were at one time continuous features, although the reduction in height appears to be a

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FIGURE 12. Pattern of distributary ridges near Rimrock River spreading out from one main cross-valley moraine. *Photo: J.T.A. 61-2-4, 3 July 1961.*

primary feature and little evidence was noted of secondary modifications by running water. Sometimes one of the main moraines is paralleled by a smaller ridge; an excellent example of this form of development is seen with MR I (Figure 11C). In places the branching of a distributary ridge from the main moraine can eventually be traced to a faint terrace on the main ridge which eventually widens and gradually forms a distinct ridge-like form (Figure 11C).

The crests of the moraines are gently undulating, with an occasional col or notch incised into the ridge. Sim (personal communication, 1962) has noted similar features on the cross-valley moraines of Generator Lake.

The stratigraphic relationship between the moraines and the central kames is obviously of major importance in ascertaining the depositional history of both forms. Two possibilities exist: either the till of the moraine, and indeed the moraine itself, continues beneath the central kames (Figure 11D), or else the moraine is entirely absent, and the till and bedded sands are in juxtaposition, with one deposit entirely displacing the other. As has been previously noted, the relative position of the central kames to the cross-valley moraines does vary. In places the two forms merge without any evidence of a morphological break, whereas in other areas the high knolls of sands and gravels are disassociated from the moraines. This is especially true of the Isortoq valley (Figure 13). If the two forms were irrevocably linked spatially in all instances, then the origin of the two main elements must be a product of two different processes operating concurrently along the

same deposition line, or else a change in process along the length of the moraine. However, there is a sufficient number of observations where there is no connection between the two forms to suggest that they are the result of two different processes (this is necessary to explain the difference between the till and the bedded deposits) acting at slightly different times, and in places, probably, concurrently.

No answer to the problem of the age relationship of the two forms was gained after a study of exposures in the Rimrock valley, although the results of a detailed study of air photographs, including enlargements at a scale of approximately 1:16,000, implies that the central kames are smeared onto the cross-valley moraines and are thus younger in age. A somewhat similar association of forms was observed by Hoppe (1952) in northern Sweden, where the Rögen type of moraine is found in association with eskers that are younger than the moraines.

Description of R II

In order to draw together certain of the previously noted generalizations of the cross-valley moraines, and to clarify further some of their more important characteristics, a short description is given of R II. This moraine is in many ways typical of the Rimrock valley moraines and since four till-fabric studies were undertaken on this ridge a detailed description is warranted. Figure 14 has been drawn both from field sketches and measurements, and from photographs. The moraine is 11 feet high where it is cut

FIGURE 13. Central kames in Isortoq valley, mainly appearing as discrete conical units not associated with any individual cross-valley moraine. Looking down-valley. *Photo: J.D.I. 61-120, 21 July 1961.*

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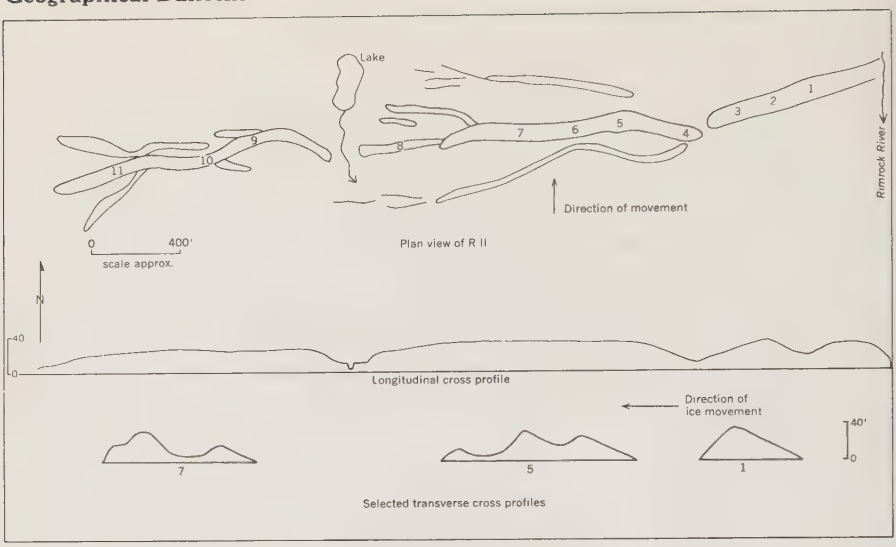

FIGURE 14. Detailed profiles and plan of R II moraine, Rimrock Valley.

by the river, and it rises to 35 or 40 feet above the adjacent swales *1*.* The distal face has a slope of 38°; the proximal face has a slope of 24°. The boulder cover is moderate, and mantles 20 to 50 per cent of the total moraine surface. The crest of the moraine falls to a low col *2* and then rises again, so that at *3* it is about 25 to 30 feet wide with a very steep distal slope. The crest then descends to another col *4*, and at this point the main ridge is joined by a subsidiary ridge on its proximal side. The col is floored with sands and gravels, heavily impregnated with silts, and is 15 feet above general ground level. The moraine increases in height to *5* and the subsidiary proximal ridge is orientated approximately parallel to the main ridge. The very steep distal slope is a continuous feature along the entire length of R II. A minor, distal, sub-parallel moraine disintegrates into a maze of rectilinear ridges. At *6* the main proximal subsidiary ridge almost joins R II, while at *7* a secondary moraine joins it, and a series of small ponds have been dammed up between the two ridges. R II then swings south and ends abruptly, but is continued by a smaller moraine which joins R II between points *7* and *8*. The subsidiary ridge on the proximal side becomes progressively fragmented, and eventually disappears in a confused network of boulder-covered ridges and hollows. As R II ascends the hillside the surficial boulder cover increases, and eventually blankets the moraines

*The numbers in this paragraph refer to the numbers in Figure 14.

entirely. At *9*, *10*, and *11* a series of small moraine ridges join and leave R II, the main ridge eventually fading out into an area of ridges and slight hollows, completely covered with angular shattered rock.

CROSS-VALLEY MORAINES OF THE MIDDLE ISORTOQ RIVER VALLEY

The investigation of the cross-valley moraines in the middle Isortoq River valley (Figure 1) was rather more cursory, and neither the descriptive analysis nor quantitative measurements were as detailed as those undertaken in the Rimrock valley. Two areas were studied: the first area lies 8 miles upstream from the junction of the Rimrock and Isortoq rivers (Figure 15) whereas the second area lies to the south of this junction.

In the first study area glacial striations and *roches moutonnées* on the valley floor show that the last recorded ice movement was directed along the axis of the valley, the orientation of the striations varying as the axis of the valley shifted. Orientations thus varied from N 50° E to N. No crossing striations were found. Above the valley the indications were that the regional ice movement had been in a general northeasterly direction.

Figure 15 illustrates the broad pattern of the cross-valley moraines. One of the most striking aspects of this pattern is their orientation in tributary valleys. In many cases they do not run transverse to the valley, but parallel to its axis, although in other cases they are transverse. However, if they are examined in relation to the Isortoq moraines, then a pattern of broadly curving morainic arcs is discernible (Figures 15 and 16). The curvature is directed inward to the former direction of ice movement, and a similarity cannot help but be drawn between this pattern and the broad, curving, calving bay of Conn Lake (Figure 3). The moraines are not so massive as in the Rimrock valley, and they vary from 2 to 15 feet in height. They have a more linear form, and exhibit only a slight tendency to bifurcate, though one ridge crosses directly over another and both continue their course without any noticeable alteration. The distal slopes, that is the north- or northeasterly-facing slopes, are appreciably steeper than the proximal slopes. Certain moraines reach the river, though in most cases the areas adjacent to the river are characterized by a series of central kames, of which the more massive members are 100 feet high (Figure 13). Several of the central kames are intimately associated with individual cross-valley

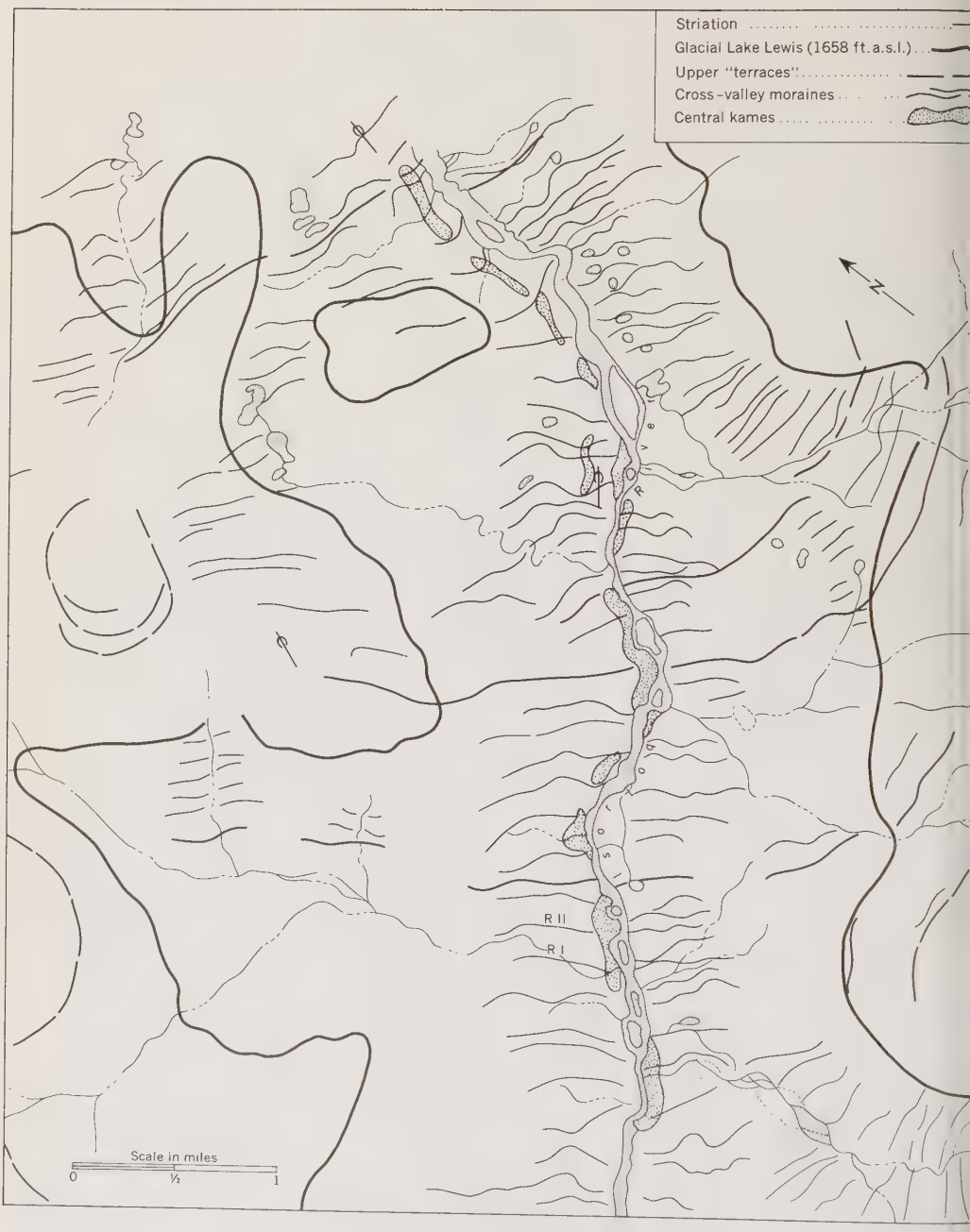

FIGURE 15. Map: Isortoq area, showing cross-valley moraines and major terraces.

FIGURE 16. Cross-valley moraines near upper bend of the Isortoq River. Note, on the right, the very simple lobate pattern of the moraines with central kames along the centre of the valley. Further along the Isortoq River the pattern becomes much more complicated. Terraces can be seen in association with the moraines. *Photo: RCAF vertical No. A-17044-29, 23 July 1961.*

moraines, but on the other hand, many are isolated knolls of sand (Figure 13). Several exposures through the moraines indicate that they are formed of identical material to the ground moraine.

The stratigraphic relationship of the central kames and cross-valley moraines was clearly seen in one exposure where bedded sands overlie and overlap a central core of till that is being exposed. The moraines are thus the older of the two deposits and have been blanketed by younger deposits of sands and gravels.

In the second study area the situation is different: the central kames are non-existent, but river-bank exposures show that the moraines were formed of sands and gravels, poorly bedded, with a litter of well-rounded boulders and cobbles. The river-bank exposures also showed that the composition of these moraines did not differ from the material flooring the

intervening swales. On the west side of the valley the moraines are rather simple linear forms, with an average height of 10 feet and less. However, on the bend of the Isortoq River opposite the Rimrock River valley, they are visually the most complex that have been seen. Ground observations are lacking, due to inability to ford the river.

GENERAL DISCUSSION

The Relationship of the Cross-Valley Moraines to Former Glacial Lake Shorelines

In the Rimrock valley the cross-valley moraines are all located below the level of glacial lake Lewis, 1,658 feet above sea level (Ives and Andrews, Figure 2), though the inter-relationship of ice movement, ice gradient, and location of the main overflow of this lake proves that the moraines must have been formed in an earlier and higher glacial lake. A deeply cut gorge to the south of Rimrock Lake has an elevation of 1,817, $\pm$ 10 feet above sea level, and appears to be the first main spillway above the 1,658-foot level. Once the ice retreated from the Isortoq-Rowley river watershed, lakes were dammed up between the ice front and the height of land; as the ice withdrew to the south, successively lower cols were uncovered, thus promoting successive falls in lake level. It is postulated that the majority of the cross-valley moraines were formed in a frontal or sub-glacial position under approximately 400 feet of water, though MR I and MR II, because of their position opposite the 1,658-foot overflow were possibly formed under approximately 300 feet of water.

The continued expansion of an ice-dammed lake in the Rimrock drainage basin is postulated on theoretical grounds: studies in the immediate field area (Ives, 1964) suggest that the upper terraces were formed principally by lateral meltwater or wave action or both in confined lateral glacial lakes. No ice-pushed ridges were noted. In some areas, small sections of dissected kame terraces are associated with the terraces, proving their marginal origin. The shoreline of glacial lake Lewis marks two well differentiated zones: the upper zone has well-developed crustaceous lichens growing on the rocks, with *Rhizacarpon geographicum* having maximum diameters of 100 mm; whereas below the shoreline this lichen species has a maximum diameter of 30 mm. The shoreline of glacial lake Lewis is also marked by well-developed ice-pushed ridges. The lake is probably entirely frontal, but it is related to a col which must have been used by earlier

frontal and lateral lakes. Thus, it is impossible to ascertain at which phase the cross-valley moraines were notched by lake water.

The situation is much more complicated in the Isortoq River valley, and the restricted area of the field survey makes a complete evaluation impossible at this stage. Several of the moraines are notched by the shoreline of glacial lake Lewis, and several have been traced onto the summits of the hills bordering the Isortoq River, which rise to about 1,800 feet above sea level (by aneroid measurements). The series of terraces above this level has been studied by Ives (1964), and their complicated history is all too evident. Field work in the upper Isortoq drainage basin will help in the elucidation of this problem. However, the withdrawal of the ice cap from the eastern Isortoq watershed would have resulted in the creation of a glacial lake ponded to the height of the eastern col. As the ice cap receded toward the west and south, the glacial lake would expand in size, and probably in depth, though this depends on the availability of lower cols. All that can be stated now is that the moraines in the first Isortoq study area were formed prior to the opening of the 1,658-foot col on the west side of the Isortoq. This is evident as the moraines are cut by the shoreline. The moraines in the second area were probably formed as the ice retreated down the valley, and the col of glacial lake Lewis must have been in operation. The moraines of these two areas were thus formed at different times and under glacial lakes of different elevation.

The Pattern of the Cross-Valley Moraines in Other Areas

It would be a mistake to regard all references to cross-valley moraines as related only to the previously mentioned forms, although it is true that there are certain common characteristics. However, these do not hide the differences, and any thesis on the origin of the moraines must at present be limited to the area of study. There is evidence to suggest that these similar forms resulted from different glaciological environments.

In the upper Isortoq and its main upper tributary (Figure 1) a simple pattern of cross-valley moraines was traced on the air photographs. The moraines are broadly curving, linear ridges, trending transverse to the valley axis. The pattern is similar to a broadly curving, calving bay (Figure 6) (cf. Hoppe, 1952). In the main tributary valley there is a regular sequence to the pattern, with a broad, massive ridge followed by a series of 10 to 15 smaller ridges. Interspersed with the moraines is a series of conical kames.

with one main system occupying the centre of the valley and broken sub-parallel series in other areas, notably the valley sides. They form a sequence of features trending perpendicular to the moraines. They appear to have some of the characteristics of the so-called 'beaded eskers' of De Geer (Bergdahl, 1953). Air photograph interpretation of the area suggests that here, even more than in the field areas, the kames are not related to the cross-valley moraines, and very few are associated with an individual moraine. In the upper portion of the Isortoq valley it is noteworthy that the main terrace, below which the cross-valley moraines terminate, is dissected by glacial drainage channels. This fact implies that the ice in the valley was retreating as a calving bay, with ice on the hillside thus being somewhat in advance of the ice cliff fronting the lake.

South of Bieler Lake the receding ice margin slopes gently into the rather shallow lake containing a whole series of linear, cross-valley moraines. They appear to have been formed by the concentration of dirt from the marginal shear planes, and they are similar in formation to the Baffin type moraines described by Goldthwait (1951b). Here, however, the lake is shallow, whereas in the middle Isortoq and Rimrock river valleys the glacial lakes were very deep. It is thus suggested that the origin of the two types of cross-valley moraines differs fundamentally.

Suggested Mechanisms of Formation of the Cross-Valley Moraines

The analysis of the moraines and associated glacial forms has been descriptive, and little attempt has been made to interpret the significance of certain characteristics. This approach has been intentional. The distribution of the moraines, limited to areas of former glacially dammed lakes, indicates that any hypothesis of origin must take into account the undoubted fact that they are sub-lacustrine glacial deposits. The development of cross-valley moraines south of Bieler Lake shows one possible mechanism of formation, though it is considered that this cannot be applied to all examples.

Five working hypotheses for the formation of the cross-valley moraines are proposed. No attempt is made at this point to fully justify the selection of these hypotheses, although the basic reasoning is discussed briefly. It is further suggested that each explanation is feasible and that any conclusion as to the precise origin of the moraines must be considered within this broad framework of multiple-working hypotheses. They are intended to

provide a basis for a quantitative analysis (Andrews, 1963) of the moraines to be published separately, as well as to rationalize the mass of descriptive data that has been included in this paper.

The first is based on the sinuosity of the ridges and their tendency to form tributary and distributary ridges. These facts, taken in isolation, are suggestive of an origin similar to that attributed to sub-glacially engorged eskers (Mannerfelt, 1945). However, this hypothesis, although it adequately describes the external characteristics of the ridges, must be precluded as it does not explain their internal structure nor the lack of stratified material in the actual ridge.

The second proposes that the cross-valley moraines are frontal features emplaced under deep-water conditions. This hypothesis should be considered carefully as it would appear that Goldthwait (1951b) also considered the Generator Lake cross-valley moraines as a linear series of frontal deposits. In the field areas, the material in the moraines is undoubtedly till and it exhibits none of the sorting that might be expected under deep-water sedimentation. The use of the term outwash deposits by Goldthwait is not considered justified; nearly all the tills in the area are rather sandy with a low silt/clay content, and the falling of material from the steep ice cliffs would produce some degree of sorting. Further, if meltwater streams were finding their way down through the terminal crevasse zone near an ice cliff, the resulting deposits would be aligned at right angles to the ice margin and not parallel to it.

The third hypothesis is similar in some ways to the second in that it is suggested that the cross-valley moraines are frontal glacial features, but it proposes that they are formed by the movement of material along shear planes, with deposition in shallow water. This hypothesis has at least a possible present-day example in the area south of Bieler Lake. However, these examples are in places obviously ice-cored and none of the features of the moraines in the field area suggested that they contain an ice core. Furthermore, it is certain that the moraines in the Rimrock valley were formed under deep-water conditions, so this hypothesis cannot apply to all areas. It is possible that the very broad, cross-valley moraines in the upper headwaters of the Isortoq and its tributary were formed in this manner as their height above sea level relative to the lowest col indicates that the former glacial lakes were shallow.

The fourth hypothesis takes into account the asymmetry of the cross-valley moraines which could be explained by assuming that they are

'satzendmoranen', or push moraines. This proposal does help to explain the asymmetry of the moraine profiles, but the number of the moraines and their branching pattern are basic factors in the rejection of this hypothesis, though it is suggested that this mechanism might operate in conjunction with another process.

The final hypothesis is that the cross-valley moraines are formed by the squeezing of basal till into a crevasse system; behind the ice front in a calving bay the crevasse pattern is a product of increased flow into a glacial lake and tension produced by the tendency to buoyancy of the ice front. The broadly arcuate pattern of the cross-valley moraines, which resembles a calving bay, is a very strong point in favor of the proposal, as is the series of off-set moraines, which closely resemble the crevasse pattern on a calving glacial tongue. However, the general complexity of the moraine pattern is rather difficult to explain by this thesis, especially the pattern of the distributary ridges.

There is of course a sixth possibility: that the cross-valley moraines are a product of any of a series of combinations of the above mechanisms.

The setting up of a series of working hypotheses, which have been examined, albeit cursorily, indicates the problems that must be faced in seeking a valid explanation for the formation of the cross-valley moraines. It is realized that the advantages and disadvantages of each hypothesis have been only outlined, and a more critical appraisal is left to the second paper which deals with the quantitative aspects. Even then, caution must be exercised, for without more detailed and precise field work, solutions to the problem of the cross-valley moraines must be limited to the immediate field area. Factors which seem striking in one field area must be shown to be significant in other areas before a general thesis of formation can be proposed or accepted. The cross-valley moraines of north-central Baffin Island are a distinct glacial form that developed under distinct glaciological conditions, and study of their various facets will illustrate the depositional role of a retreating arctic glacier discharging into, or fronted by, a glacial lake.

References

Andrews, J. T.

1963: The cross-valley moraines of north-central Baffin Island: a quantitative analysis. *Geog. Bull.*, No. 20, (in press). *Geographical Branch*, Ottawa.

Bergdahl, A.

1953: Marginal deposits in south-eastern Sweden, with special reference to the oses. *Lund Studies in Geography*, Royal University of Lund, Sweden, Series A, No. 4. 24 p.

1959: Glaciofluvial estuaries on the Narke Plain. *Svensk Geogr. Arsbok*, Arg. 35: 47-71.

1961: Glaciofluvial estuaries on the Narke Plain, II, the lower Kvismar valley. *Svensk Geogr. Arsbok*, Arg. 37: 71-91.

Craig, B.

1961: Surficial Geology of Northern District of Keewatin, Northwest Territories. *Geol. Surv. Can.*, Paper 61-5. 8 p.

Goldthwait, R. P.

1951a: Deglaciation of north-central Baffin Island (abstract only). *Geol. Soc. Am. Bull.*, vol. 62, 1443-4.

1951b: Development of end moraines in east-central Baffin Island. *Jour. Geol.*, vol. 59, 567-577.

Holdar, G. G.

1952: Problemet Torne-Issjon. *Geogr. Annal.*, vol. 34, 73-88.

Holmes, C. D.

1947: Kames. *Am. Jour. Sci.*, vol. 245, 240-249.

Hoppe, G.

1952: Hummocky moraine regions with special reference to the interior of Norbotten. *Geogr. Annal.*, vol. 34, 1-72.

1959: Glacial morphology and the inland ice recession in northern Sweden. *Geogr. Annal.*, vol. 41, 193-212.

Ives, J. D.

1964: The terrace forms of the upper Isortoq River, north-central Baffin Island—a study of the deglacierization process. *Geog. Bull.* (in press). *Geographical Branch*, Ottawa.

Ives, J. D. and Andrews, J. T.

1963: Studies in the physical geography of north-central Baffin Island, N.W.T. *Geog. Bull.* No. 19, 5-48. *Geographical Branch*, Ottawa.

Lee, H. A.

1960: Sakami Lake surficial geology. Map 52-1959. *Geol. Surv. Can.*, Ottawa.

Lundqvist, G.

1937: Sjösediment fran Rögenomradet i Hajedalen. *S.G.U.*, Series C, No. 408.

Mannerfelt, C. M: son.

1945: Några glacialmorfologiska formelement. *Geogr. Annal.*, vol. 33, 166-209.

Sissons, J. B.

1958: Supposed ice-dammed lakes in Britain with particular reference to the Eddleston valley, southern Scotland. *Geogr. Annal.*, vol. 40, 160-187.

LAND ABANDONMENT IN PRINCE EDWARD ISLAND

C. W. Raymond and J. A. Rayburn

ABSTRACT: A comparison of air-photograph coverages of Prince Edward Island of 1935 and 1958 indicate that a large amount of land has been removed from agricultural production. Most of this land either has or will revert to forest in a few years. The reasons for the abandonment are discussed.

The steps in the reversion from agricultural land to forest are described and the various areas of the island are discussed in relation to them. Recent agricultural developments on marginal land are also discussed.

RÉSUMÉ—Un parallèle entre les photos aériennes de l'Île-du-Prince-Édouard prises en 1935 et en 1958 permet de constater que l'agriculture ne se pratique plus sur un grand nombre de terres. Dans la plupart des cas, ces terres sont déjà reprises par la forêt, ou elles le seront d'ici quelques années. Le présent travail vise à étudier les diverses raisons qui ont motivé l'abandon des terres.

Les auteurs décrivent les étapes de la reprise par la forêt des terres propres à l'agriculture, et ils font l'examen des diverses régions de l'île en fonction des étapes susmentionnées. Ils examinent également les tentatives récentes de mise en valeur agricole dans les secteurs considérés comme plus ou moins productifs.

INTRODUCTION

The most significant change in the land use of the Maritime Provinces during the last 70 years has been the reduction in the acreage of cleared agricultural land. Between 1891 and 1956 improved agricultural land decreased by 68 per cent in Nova Scotia, 37 per cent in New Brunswick and 15 per cent in Prince Edward Island.* Although the trend has been much less marked on the island, it has been caused by many of the same factors and it may be measured with greater accuracy than in either Nova Scotia or New Brunswick. From a comparison of the air-photograph coverages of the island taken in 1935–1936 and in 1958, it is possible to delineate the entire acreage removed from cultivation during that period. A full assessment of more recent abandonment was facilitated by a field-by-field land-use survey undertaken by the writers during the summer of 1959.

THE PHYSICAL LANDSCAPE

Drainage, slope, and the texture and composition of surface deposits have greatly influenced the pattern of land abandonment on Prince Edward Island. The province is the upland portion of a sedimentary lowland, underlain by horizontal beds of soft, red sandstone and shale. The original deposits and bedrock surface were extensively reworked during the last

*Source of statistical data is Dominion Bureau of Statistics, unless otherwise stated.

MS submitted May 1962.

glaciation leaving behind a thick mantle of predominantly sandy till on which the soil profiles have developed. Under the influence of the cool, moist climate, a typical podzolic type of profile has developed, low in natural fertility, and strongly acidic. Good land management and fertility practices are essential in sustaining agricultural productivity even on the well-drained, fine, sandy loams and clay loams which are rated as 'best' (Whiteside, 1950, p. 57). More than half the island's soils are rated 'best', the largest concentrations being in eastern Prince and central Queens counties. A somewhat smaller area occurs in the O'Leary-Elmsdale region of western Prince county, and there are local concentrations in the Morell, Souris, and Guernsey Cove districts of Kings county. Throughout the rest of the island, most soils are either poorly drained or have a low moisture-holding capacity.

Local relief also has considerable influence on the province's land use. The best agricultural areas are associated with slopes between 2.0 and 4.0 per cent (Figure 1). Extensive areas of flat terrain with less than 2.0 per cent local relief lie close to sea level in west-central Prince county. They are very poorly drained, as are the valley bottoms and depressions in northern Kings county. In the two major hilly areas, western Queens, and the Caledonia area straddling the Kings-Queens county border, average slopes exceed 4.0 per cent and there is excessive drainage and erosion.

PATTERN OF SETTLEMENT

Settlement of Prince Edward Island followed the conclusion of the Seven Years War (1756-63). Agricultural clearings were concentrated along the coast. The irregular grid system of the original survey is still evident in the cleared land pattern, particularly in eastern Kings county where linear clearings are separated by broad expanses of forest. With the great immigration of Scottish and Irish settlers between 1830 and 1850, land settlement penetrated all but western Prince county which was not fully settled until the latter part of the nineteenth century. Typical of Eastern Canadian settlement, little attention was paid to the agricultural potential of the land. Moreover, much of the hilly and poorly drained land of the interior was settled by Scots and Irish who came to the island with little experience in mixed crop and livestock farming. By 1891, 87 per cent of the total land area had been taken up in farms. The average holding was only 80 acres of which 30 acres remained in forest.

After 1891, rural population declined coincident with the opening of the Canadian West and with industrial expansion in Central Canada and

New England. However, despite this and although abandonment had begun as early as 1891 in the poorer lands at the extremities of the island, the amount of improved acreage continued to grow in the central part until 1931 and in a few census subdivisions until 1941. Hence, the over-all contraction in improved acreage was negligible between 1911 and 1931, despite a continuing decline in rural population totals. The fur-farming industry in the 1920's, the beginning of potato specialization, and the economic depression after 1929 all served to maintain improved acreage at between 765,000 and 770,000 acres during this period. (*See* Figure 2.)

Only since the late 1930's has the major contraction in improved farmland taken place. In fact, out of a total reduction of 123,648 acres since 1911, 120,280 have been abandoned since census year 1931 and 74 per cent of this later total went out of production between 1941 and 1951, the decade during and following World War II.

The widespread introduction of tractor power that began on island farms during the 1940's led inevitably to an increase in the size of the average farm unit, together with the abandonment of fields not suited to mechanical cultivation. Farm mechanization, along with improved farm management, permitted the production increases necessary to sustain farm incomes, but it also placed the small farms and less efficient farmers in an increasingly marginal position. During the same period enlistment in the armed services, war industries and the post-war industrial expansion in central Canada provided an abundance of employment alternatives that had not been available during the 1930's. More recently, the inauguration of universal old-age pensions has encouraged elderly people to cease farming, and the inception of unemployment insurance benefits for fishermen during off-season has led to less emphasis on farming in the traditional fishing-farming economy of coastal areas.

LAND ABANDONMENT

Since forest is the natural climax vegetation in Prince Edward Island, farmland left idle for an extended period (20 years or more) will return to bush and tree growth. Available evidence allows the division of this transition from farm to forest into three stages: open grassland, scrub grassland, and reforested land—formerly cleared and cultivated land on which there has been a regeneration of tree growth through natural seeding. These stages account for 161,590 acres or 11.6 per cent of the island's area (Figure 3B).

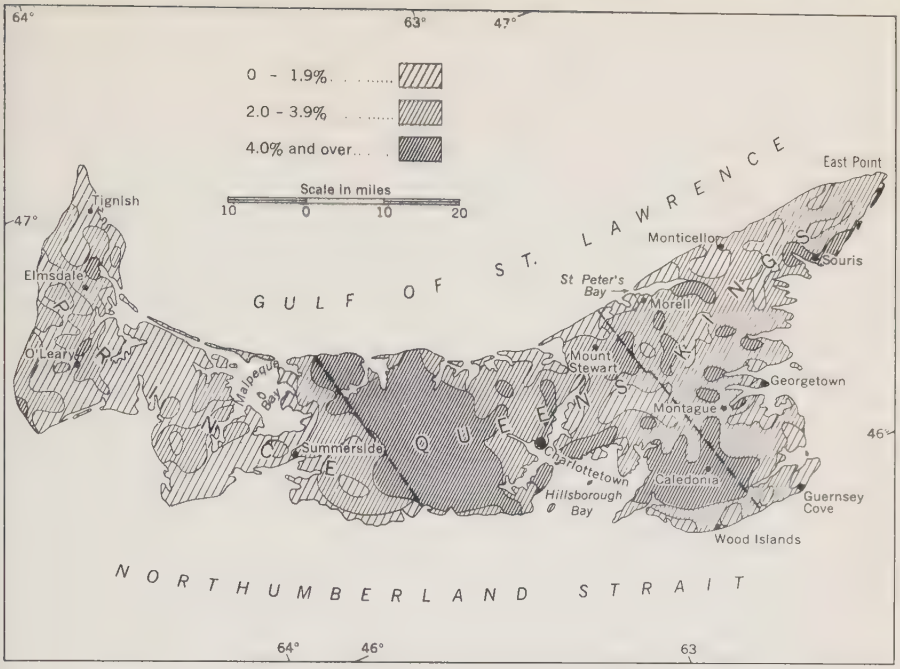

FIGURE 1. Average slope.

Open grassland includes idle grassland covered with old, uncut hay and weeds, and with or without scattered bushes not exceeding four feet in height. It represents the most recently abandoned farmland which could be returned to cultivation without extensive clearing. The 1959 land-use survey classified 60,720 acres (4.3 per cent) of the island's surface as open grassland. It was largely concentrated in the hilly and poorly drained areas at either end of the province.

Scrub grassland, which represents a more advanced stage of abandonment, includes areas covered with old uncut hay and weeds with scattered bushes exceeding four feet in height. The recent survey mapped 39,870 acres, or 2.9 per cent of the surface, in this category distributed in a pattern very similar to that of open grassland.

Reforested land, includes formerly cleared and cultivated land on which there has been a regeneration of tree growth through natural seeding. A comparison of the air photographs taken in 1935-1936 with the land-use data secured in the 1959 field survey revealed that 61,000 acres, or 4.4 per cent, of the surface reverted to forest through natural regeneration during this period, and 2,750 acres had been burned over for blueberry production. However, 1,620 acres of woodland, principally farm woodlots in 1935, had

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been converted into cropland by 1959. The distribution of this reforested land withdrawn from cultivation since 1935 is shown in Figure 3A. Net abandonment previous to 1935 was negligible (Figure 2) and, therefore, has been disregarded. An examination of the 1935-1936 air photographs revealed a number of reforested areas. But since it was found that many of those clearings which had reverted to forest after 1935-1936 were indistinguishable from surrounding forested areas on the 1958 air photographs, it was decided that an accurate delineation of areas abandoned prior to 1935-1936 would be questionable through interpretation of the earlier photography.

The reduction in cultivated acreage has been much less marked in the central part of the island where the best agricultural soils are most widespread; between Malpeque and Hillsborough bays only 6.7 per cent of the

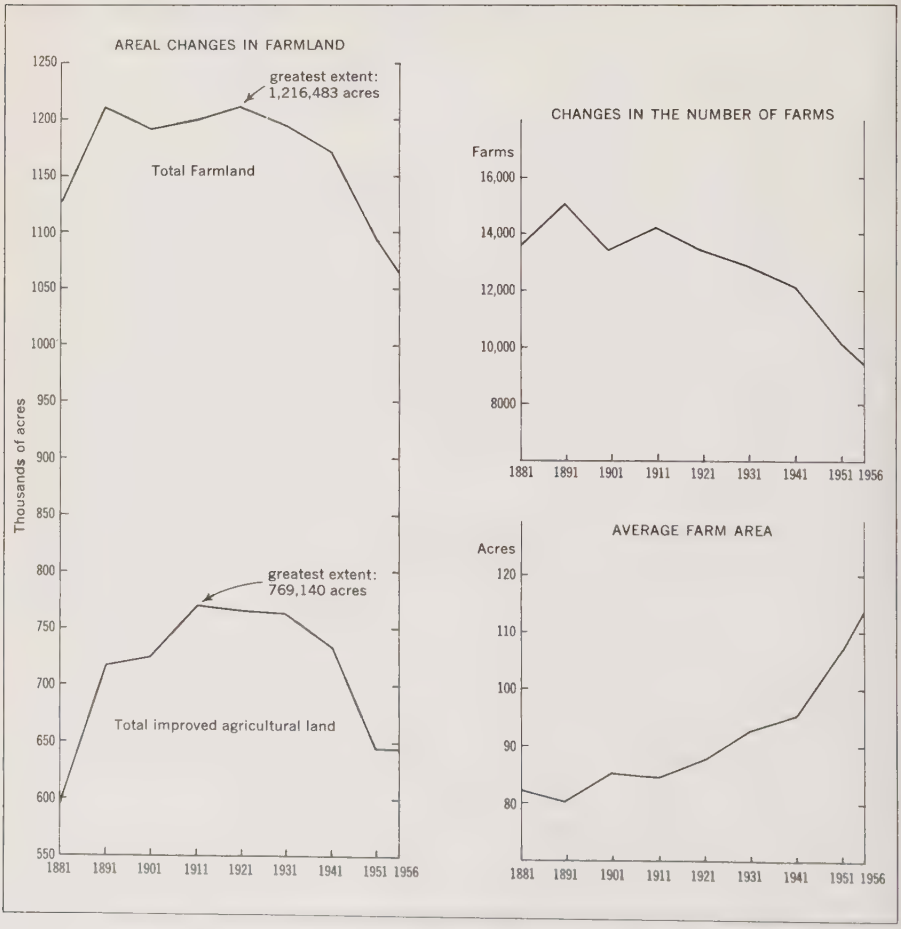

FIGURE 2. Basic changes in area and number of farms, 1881-1956.

FIGURE 3. A. Distribution of cleared agricultural land returned to forest through natural regeneration since 1935.
B. Distribution of cleared land removed from farm cultivation between 1935 and 1959.

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surface falls within the abandonment categories as compared with double this percentage (12.4) in the western end of the island, and almost three times this percentage (16.0) in the eastern end. These proportions are similar for both the reforested land and the combined open and scrub grassland stages, as in tabulation.

Open and Scrub Grassland, and Reforested Land as a Percentage of Total Area, by Region

	Open and Scrub Grassland		Reforested Land		Grassland and Reforested Land	
	Acreage	Per cent of Total Area	Acreage	Per cent of Total Area	Acreage	Per cent of Total Area
Western Prince County	26,310	8.2	12,900	4.2	39,210	12.4
Central P.E.I.	21,380	4.3	9,030	2.4	30,410	6.7
Eastern P.E.I.	52,900	9.1	39,070	6.9	91,970	16.0
Total	100,590	7.2	61,000	4.4	161,590	11.6

More than 70 per cent of the central part of the island has been cleared for agriculture and contains the best managed and most productive farms in the province. Gentle slopes, covered with easily cultivated fine, sandy loams predominate except in a belt of hills in western Queens county. Livestock holdings, the quality of forage crops, and the acreage of farmland devoted to tilled crops (grain and potatoes) are all significantly higher than elsewhere in Prince Edward Island. Most of the abandonment has been in the hilly belt of western Queens county. Although these hills comprise only 17.5 per cent of the central area, they contained 29 per cent of its open and scrub grassland and 56 per cent of its reforested land in 1959.

The western part of the island is generally flat, poorly drained and marginal agriculturally. The only major exception is the belt of prosperous farms between O'Leary and Tignish which contains almost half the cleared farmland in the region. Land abandoned since 1935 includes 11.1 per cent of the surface to the southeast of O'Leary and almost one-fifth (18.2 per cent) of the surface along the northwestern shore.

The eastern end of the island varies greatly in agricultural quality. Over most of the region, patches of well drained loams are pocked with small bogs and surrounded with poorly drained forested land. Between 1935 and 1959, 8.5 per cent of the region reverted from cleared farmland to forest,

and an additional 7.5 per cent of the surface was mapped as open and scrub grassland in 1959. The three categories account for one-fifth of the surface in the southern half of the region and an even higher percentage along the north shore from Monticello to East Point.

Due to the low level of land taxation and the absence of an active Crown lands policy, abandoned farms usually fall into the hands of pulpwood and timber dealers who are little interested in either agricultural production or long-term forest management. Although many of the grasslands are used for occasional livestock grazing, in most cases they eventually revert to forest. Nevertheless, profitable alternative uses have assumed local importance in recent years:

1. The 1959 survey revealed some 4,000 acres of abandoned grassland under management for commercial blueberry production. The fruit is picked from native lowbush blueberries which form part of the natural succession on the worn-out, sandy, acidic soils that are typical of much of the island's abandoned grassland. Other bushes, weeds and small tree growth are removed by cutting, spraying and burning so that the blueberry bushes may extend their coverage over the entire field. Burning is also necessary every second or third year in order to maintain satisfactory yields; it provides a simple method of pruning old growth from the bushes and of encouraging the formation of new shoots. The largest concentrations of commercial blueberry acreages are in areas of abandoned farmland along the northern Kings county shore westward from East Point, in the hills north of Wood Islands, south from St. Peter's Bay, and in association with burned-over forest land in the Mount Stewart area. Although production is feasible only where native lowbush blueberries have already been established, there are many open and scrub grassland areas throughout the island which are suited to the expansion of this enterprise.

2. A number of large-scale potato producers who have been unable to acquire additional acreage on adjacent farms, have expanded operations to abandoned farms in more isolated settlements. The locational disadvantage and land-clearing expenses are offset by the low cost of land and the optimum use of machinery on large continuous acreages.

3. Successful tobacco-growing experiments have also been undertaken on the light, sandy soils of southern Kings county, an area of extensive land abandonment. Approximately 85 acres were planted in tobacco in the

Greenfield district, west of Montague, in 1961, and any expansion in the industry is likely to involve the recultivation of open and scrub grasslands in the same area.

Reference

Whiteside, G. B.
1950: Soil survey of Prince Edward Island, Experimental Farms Service, Canada, Dept. of Agriculture in Co-operation with the Prince Edward Island Dept. of Agriculture, Charlottetown, 57.

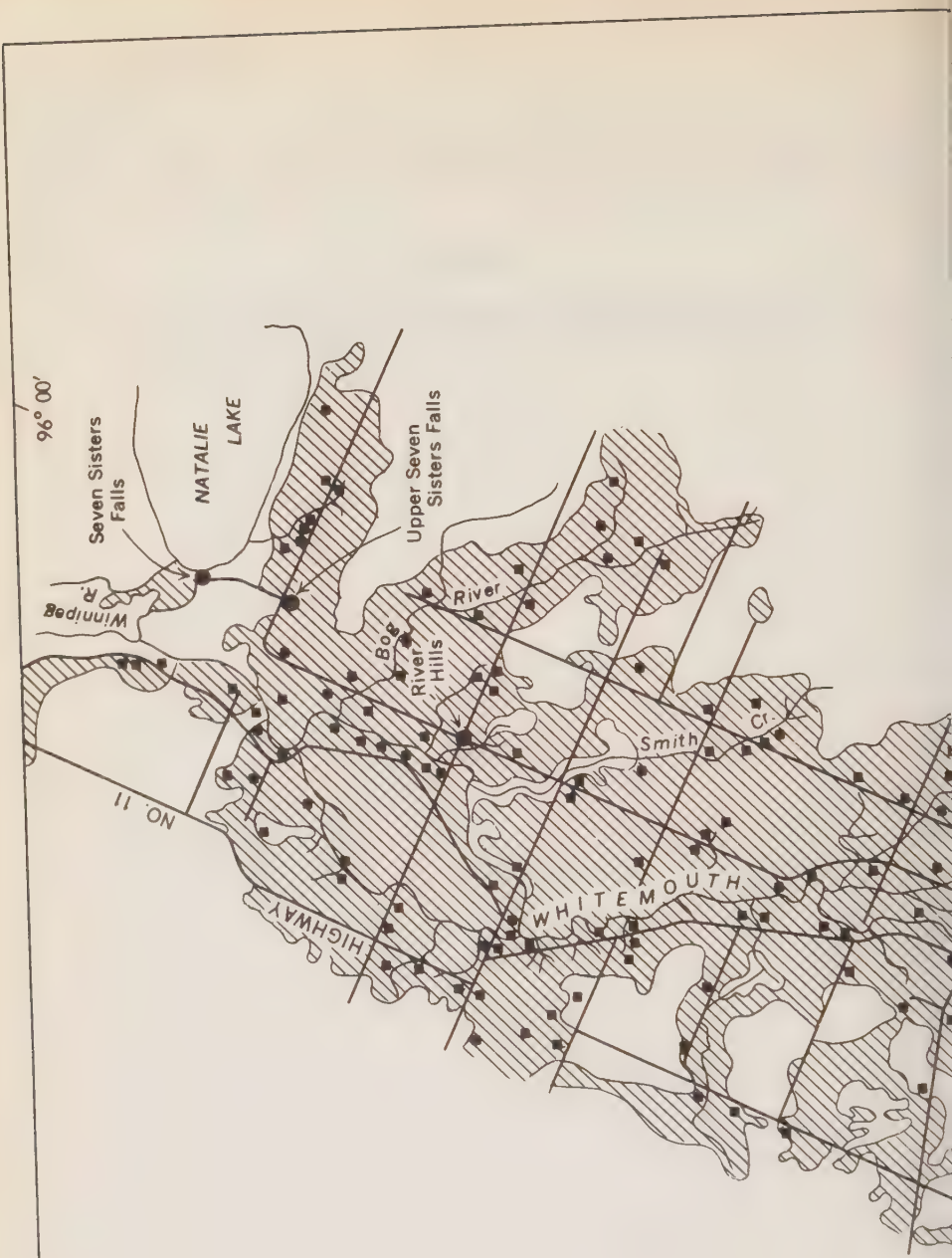


FIGURE 1. Limit of cultivated land, Whitemouth River valley, Manitoba

NO. 4
Whitemouth
RIVER
River
CANADIAN PACIFIC RAILWAY
HIGHWAY NO. 4
Bog
CANADIAN NATIONAL RAILWAYS
HIGHWAY NO. 15
50° 00'

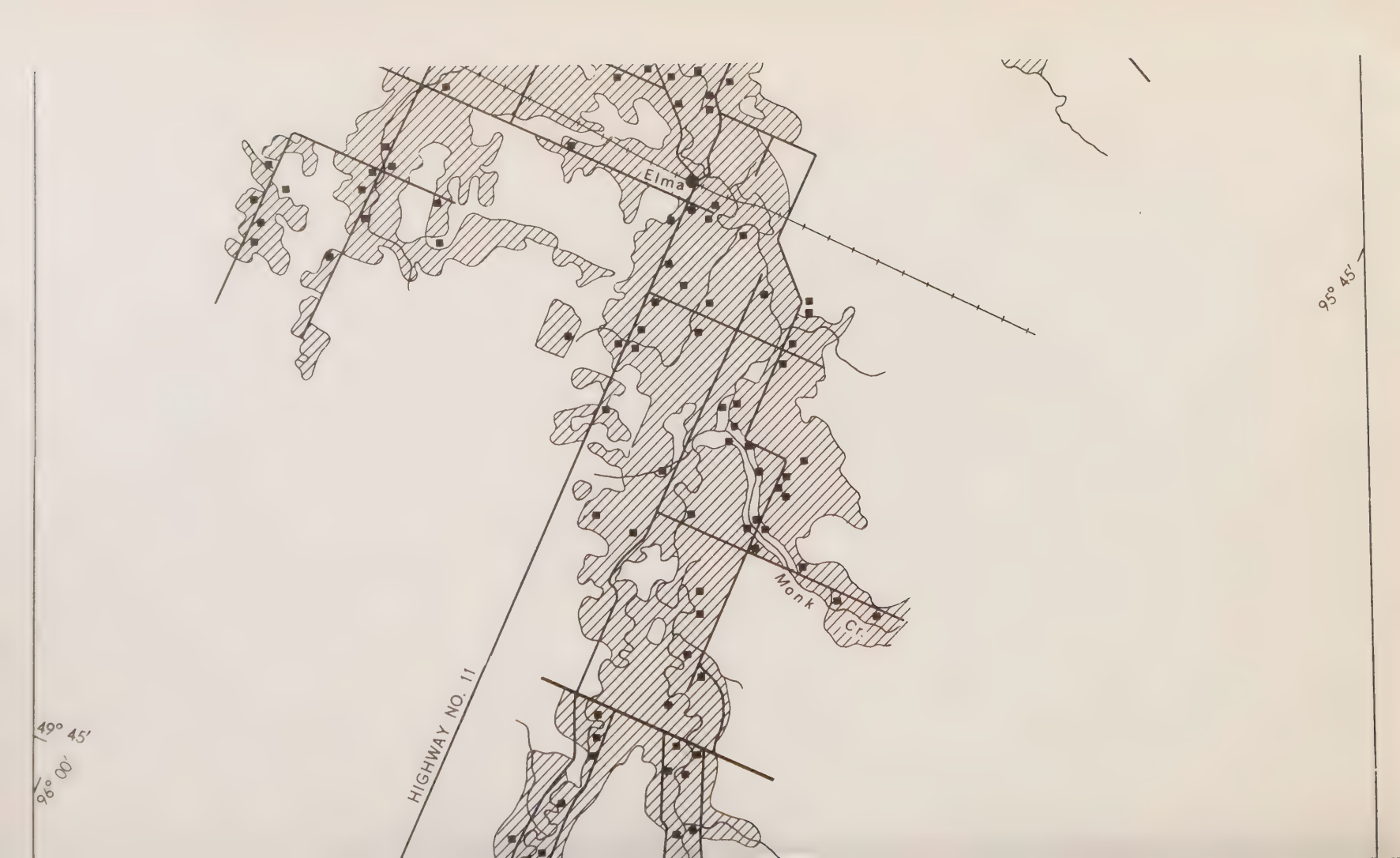
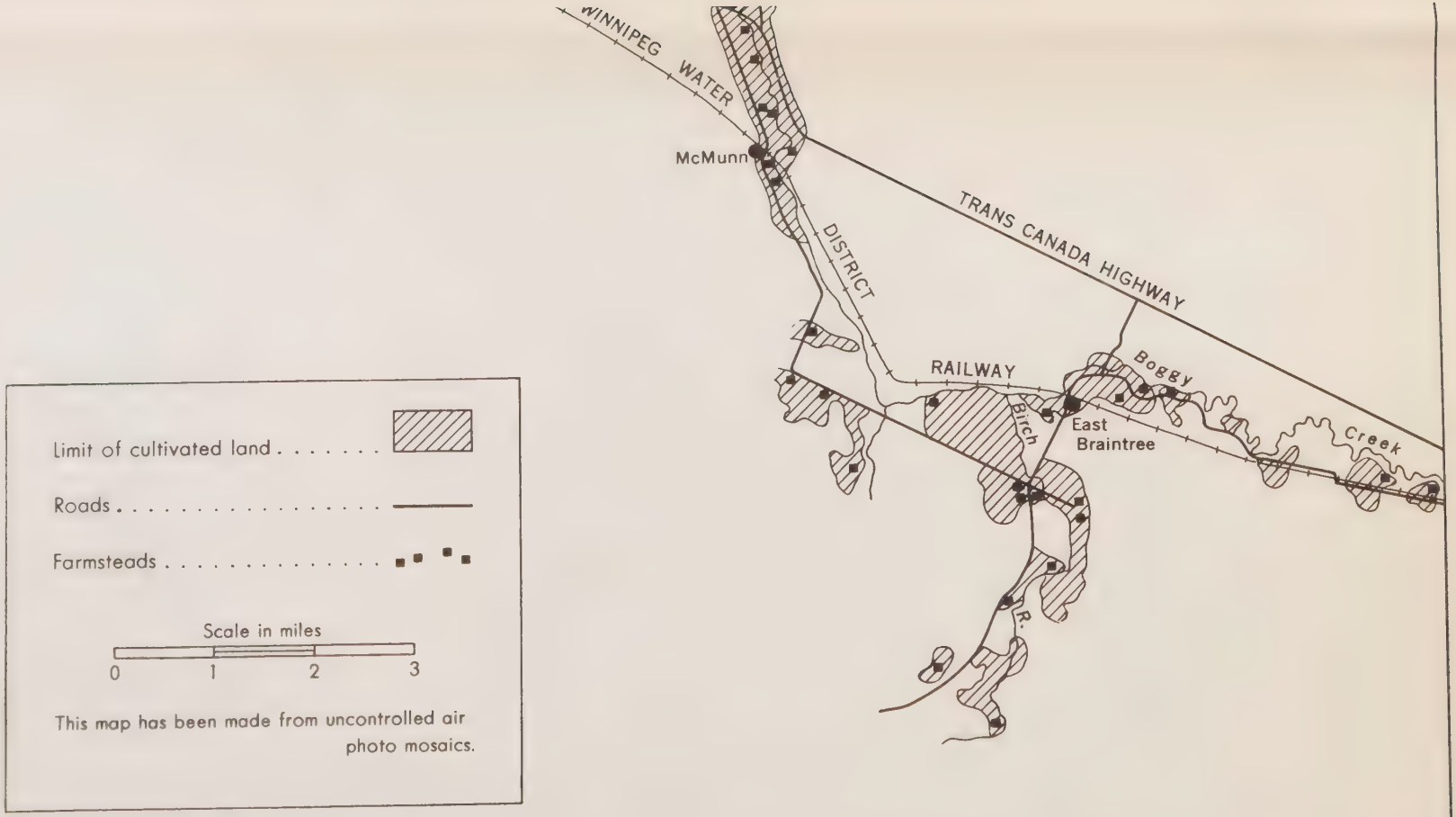

Elma
Monk Cr.
HIGHWAY NO. 11
49° 45'
96° 00'
95° 45'

FIGURE 1. Limit of cultivated land, Whitemouth River valley, Manitoba


WINNIPEG WATER
McMunn
DISTRICT
TRANS CANADA HIGHWAY
RAILWAY
Boggy
Creek
East
Braintree
Birch
R.
Limit of cultivated land
Roads
Farmsteads
Scale in miles
0
1
2
3
This map has been made from uncontrolled air photo mosaics.

95° 45′

LAND UTILIZATION IN THE WHITEMOUTH RIVER VALLEY MANITOBA

J. H. Lovering

ABSTRACT: The Whitemouth River valley, 30 miles east of the Red River plain, is an outlier of agricultural development in southeastern Manitoba. This paper describes land use in the area, and shows the relationship between it and the physical and economic conditions which restrict the cultivation of land to a narrow ribbon along the lower Whitemouth River system. Elsewhere in the valley, non-farm work is significant in the economy. Land use problems and current trends are discussed.

RÉSUMÉ—Située à 30 milles à l'est de la plaine de la rivière Rouge, la vallée de la rivière Whitemouth est une région agricole isolée dans le Sud-Est du Manitoba. Dans cette étude, l'auteur y décrit l'utilisation des terres et traite des rapports entre cette dernière et les conditions physiques et économiques qui restreignent l'étendue des terres cultivées à une étroite bande de terrains le long du cours inférieur de la Whitemouth. Ailleurs dans la vallée, les activités non agricoles prennent une grande importance économique. L'auteur traite ensuite des problèmes que pose l'utilisation des terres, ainsi que des tendances actuelles.

INTRODUCTION

The Whitemouth River valley, 30 miles east of the Red River plain is an outlier of agricultural development in southeastern Manitoba. The valley is bordered on the west by extensive bogs and sandy end moraines whereas the Precambrian Shield lies immediately to the east.

Cultivated land, which is limited to a narrow ribbon along the lower Whitemouth River system, covers only a small part of the valley (Figure 1). The remainder of the valley is, for the most part, poorly drained and peat-covered.

The number and development of tributaries to the Whitemouth River decrease markedly toward the south. Surface deposits become progressively more coarse in the same direction, with the result that the width of the cultivated strip decreases from four miles in the north to a few hundred yards in the south. The ratio of cultivated acres to rural population also decreases towards the south where per-farm cultivated areas are small. In this area, non-farm work is of major significance in the economy.

To facilitate the study of land use and its relation to physical and economic conditions in the Whitemouth River valley, four regions have been delineated using the following criteria: *1.* drainage density—number of miles of drainage channel per square mile, *2.* proportion of township

MS submitted April 1962.

under cultivation, *3.* similarity of farms as measured both by crop areas and yields, and by numbers of livestock per farm and, *4.* the ratio of cultivated acres to rural population.

The data relating to each of the four criteria were tabulated on a township basis. The townships were then grouped to form the regions. Drainage density was calculated from maps made from uncontrolled air photograph mosaics at a scale of 1:31,680. The grouping of townships to farm regions was guided by field observations. The regions are: Whitemouth, Elma, Hadashville and East Braintree (Figure 2).

PHYSICAL CHARACTERISTICS

Surface Deposits

At the conclusion of the last continental glaciation and deposition of ground and end-moraines, glacial meltwater and run-off from the Red River drainage area was ponded between the retreating ice to the north and a highland area to the south, forming glacial lake Agassiz. A bay covered this area and drift, deposited previously as ground moraine, was mantled with a relatively thin layer of lacustrine materials (Figure 3). The water-worked end-moraines form a series of ridges in the southwest.

The lacustrine deposits, thickest along the channels of the Whitemouth River system, range from fine sand to clay. The clay was deposited in the northern part of the area where the lake was deepest; the sand was laid down in the shallower waters of the south (Figure 3).

Alluvial materials ranging in texture from very fine sand to silty clay loam, are restricted to small areas adjacent to the major streams. Peat covers a very large part of the area, ranging to a depth of 10 feet north of Whitemouth Lake.

Drainage

The number and stage of development of channels of the Whitemouth River system are important factors in determining the agricultural suitability of the land of the valley. That is, the areas of imperfectly or moderately well-drained deposits, are largely determined by the development of drainage channels because of the large areas of bog and prevalence of high ground-water tables. The exceptions are the areas of droughty sands, occurring mainly as beach and end morainic deposits, which are not suited to agricultural use, owing to their acidity, low cation exchange and water retention capacities. Figure 2, showing drainage density values, (miles of

channel per square mile) and stream frequency (number of channels per square mile), indicates a marked decrease in number and degree of development of drainage channels upstream from the mouth of the system. The peripheries of the cultivated areas coincide closely with the limits of headward erosion of the tributaries.

Soils

According to preliminary data supplied by the Manitoba Soil Survey organic soils (deep and shallow peats) cover most of the area. In the mineral soils the orthic and gleyed dark grey wooded sub-groups are the most widely distributed. In the cultivated areas, where textures are locally fine to moderately fine, soils of the gleyed dark grey sub-group appear.

A nitrogen-phosphorous deficiency is typical of these soils. Soil fertility problems become more serious southward along the river owing to increasing

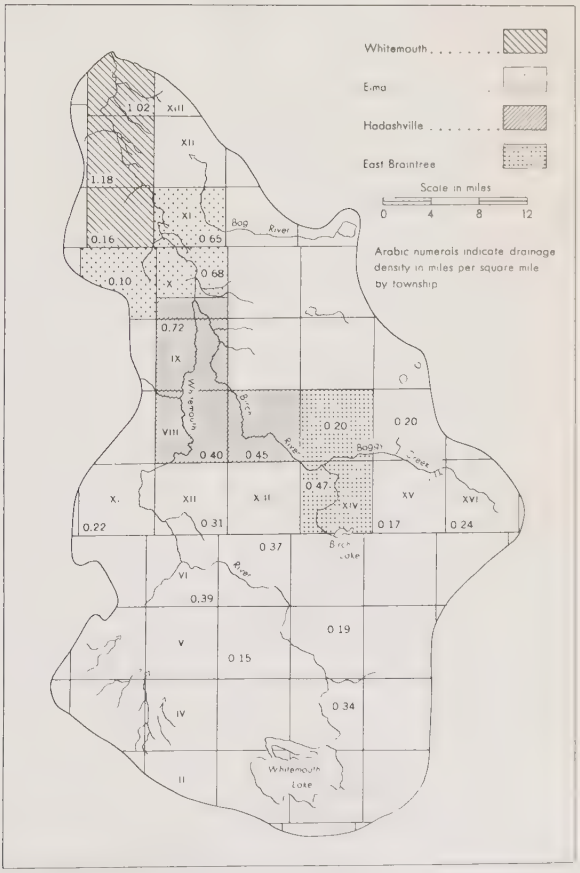


FIGURE 2. Regions and drainage density values, Whitemouth River valley, Manitoba.

proportions of coarse-textured deposits and increasingly poor drainage. Potash and sulphur deficiencies may also exist in the coarse-textured materials.

In the Whitemouth region and the northern part of the Elma region, textures are fine to moderately fine, cation exchange capacities are relatively high, and soil fertility is moderately good and easily maintained. However, in the imperfectly and poorly drained parts of these regions, soils do not become warm until late spring and the anaerobic conditions do not favor the nitrification and nitrogen fixation processes.

In the remainder of the cultivated area, materials are, for the most part, coarse and moderately coarse, of low cation exchange capacity, and soils are of low fertility. These areas of imperfectly and poorly drained soils present the same problems as previously described. The soil surfaces dry quickly so that strong, early root growth in young plants may be severely inhibited, even though ground-water tables are high in the soil.

Climate

The climate of the valley is transitional between that of the grasslands to the west and the forests to the east. A mean annual rainfall of 22 inches, with summer concentration, and a mean July temperature of 65° F produce a relatively high precipitation efficiency. This combination of rainfall and temperature, provided that soil drainage and fertility compare favorably, leads to crop yields consistently higher than those in the drier areas to the west.

The valley experiences a greater number of cool nights and a shorter frost-free season than would be expected at this latitude. Sprague, for example, to the southeast of the valley, has a mean frost-free season of 72 days whereas the valley as a whole has a frost-free season of at least 90 days. Even so, frost destruction of crops is not a common occurrence.

The fact that the period of maximum precipitation coincides with the frost-free period is of great importance to agriculture. The relatively dry conditions which prevail in March and early April are also important because they allow spring seeding operations to be completed before the rainy season begins.

Present Land Use

The data used in the following section are from interviews made in September 1960 covering about 30 per cent of the farms in the area.

Mixed farming (farms that do not have a gross income from either livestock or crops exceeding 70 per cent of the total gross income) predominates in the area. Non-farm work increases in importance from north to south so that in the East Braintree region it was the main source of income for all farmers interviewed.

Table 1 gives means of individual farm crop-areas within each region. Because of the relatively cool, wet summers, the wheat grown —as a cash crop—is a softer wheat than that grown to the west. The decreases in per-farm wheat acreages and yields south from the Whitemouth region are closely related to increasingly poor drainage and decreasing soil fertility.

Oats, better suited to the soil and climatic conditions of the area, are grown, chiefly as fodder, in relatively large amounts. The apparent concentration in the Elma region is the result of the emphasis on grain production on several farms, operated in conjunction with non-farm work.

Barley is largely precluded from the area by low yields and low per-unit market values. Flax is grown as a cash crop, most often in years with late, wet springs.

Areas of hay and pasture, frequently occupying poorly drained land, are also found, because of their importance in the crop-rotation scheme, in the better-drained areas.

Their large acreages reflect the importance of livestock and favorable physical conditions. A relatively high precipitation efficiency and high ground-water table limit the need for summer fallow except as a means of controlling weeds.

Areas under forest are usually coarse-textured, stony, and poorly to very poorly drained and hence unsuitable for agricultural use. There are smaller forest areas on steep slopes adjacent to drainage channels.

The six-year rotation scheme used by most of the valley farmers is: three years hay, one year wheat and two years oats. Flax may replace wheat, or barley may replace the first year of oats. The use of commercial fertilizer is not widespread, the general opinion among local farmers being that yield increases do not justify the cost. All available barnyard manure is used, however.

Livestock

Table 2 gives means of individual farm livestock holdings in each region. The large number of poultry in the Whitemouth and Elma regions come

FIGURE 3. Surface materials, Whitemouth River valley, Man

from several Mennonite poultry farms which have as many as 10,000 birds. Flocks on other farms in these regions, averaging about 50 birds, are maintained primarily for home use.

In 1950, contracts for the sale of fluid milk were let to 30 farmers grouped along highway 4, mainly in the Whitemouth region. This particular group was selected because they already had sizeable herds and were compactly grouped close to a good transportation route. Farms farther away from the highway usually produce milk or cream for non-contract sale. Beef cattle are often the main product from farms on poorly drained land at the edge of the cultivated area.

Table 1*

Per-farm Land Use in the Whitemouth River Valley

Land Use	Regions			
	Whitemouth	Elma	Hadashville	East Braintree
Wheat (acres)	25	22	11	1
% of farm	10	10	6	1
yields (bu/acre)	26	22	12	10
Oats (acres)	37	44	19	6
% of farm	15	20	9	3
yields (bu/acre)	35	32	23	20
Barley (acres)	7	2	1	1
% of farm	3	1	1	1
yields (bu/acre)	22	16	13	10
Flax (acres)	4	2	4	—
% of farm	1	1	3	—
yields (bu/acre)	15	13	15	—
Hay (acres)	58	44	40	52
% of farm	24	20	20	21
yields (tons/acre)	1.5	1.1	1.0	1.0
Cleared pasture (acres)	32	13	19	10
% of farm	13	6	10	2
Summer fallow (acres)	13	25	20	21
% of farm	5	12	10	9
Forest (acres)	67	64	84	151
% of farm	28	30	42	62
Average Farm size (acres)	238	217	192	221
Total no. of interviews	42	33	41	26
% of total farms	30	29	32	27

*Data from farm interviews

Table 2*

Average Per-farm Livestock Holdings in the Whitemouth River Valley

Livestock	Regions			
	Whitemouth	Elma	Hadashville	East Braintree
Total cattle (nos./farm)	25	17	11	6
Proportion of farmers owning (%)	86	87	76	57
Milk cows (nos./farm)	9	6	3	2
Proportion of farmers owning (%)	62	70	54	57
Pigs (nos./farm)	4	2	5	1
Proportion of farmers owning (%)	50	55	51	43
Poultry (nos./farm)	401	970	38	31
Proportion of farmers owning (%)	79	73	51	43

Table 3*

Proportion of Farmers Deriving Their Main Income From Each of the Common Sources

Source	Regions			
	Whitemouth	Elma	Hadashville	East Braintree
	%	%	%	%
Dairy	50	23	20	—
Beef	14	18	12	—
Grain	12	18	7	—
Poultry	5	16	—	—
Non-farm	19	25	61	100

*Data from farm interviews

There are few dairy farms in the northern part of the Whitemouth region as, before the use of trucks, the distance from the CPR loading point at Whitemouth largely precluded this specialty. The production of beef and grain continued after transportation ceased to be a problem.

Most of the cattle in the southern three regions are kept for cream production. Skimmed milk is fed to calves in the Elma and East Braintree regions and to pigs in the Hadashville region.

The relative unimportance of pigs throughout the valley is indicated by Table 2. Only in the Whitemouth and Hadashville regions are they raised commercially, usually in conjunction with the larger dairy herds which supply skimmed milk.

Farm Income

There are usually two or three sources of income of nearly equal importance on the farms in the valley, contract dairy and poultry farms excepted. Table 3 shows a classification of farmers according to their main income source.

Many of the beef and grain mixed farms are concentrated in the northern part of the Whitemouth region. Their operators usually work off the farm for a few months each year. Although livestock is the main source of income in the northern part of the Elma region, grain and non-farm work predominate in the southern section, where small acreage and only moderate soil fertility do not give satisfactory returns to the operator. As a result, non-farm work is sought and farm emphasis is turned toward grain production, even though the area is better suited to beef and forage production. Livestock and forage production are important income sources in the Hadashville region. The high value for poultry in the Elma region is due to the emphasis placed on that specialty by Mennonites.

Non-farm Work

Skilled trades, represented in the area by carpenters, electricians, mechanics and linemen, provide the main source of non-farm work in the Whitemouth River region. Construction and pulpwood are important secondary sources. The usual period spent in non-farm work by those deriving their main income from it is 5 months a year.

In the Elma region, where six months a year is the average time spent in non-farm work, pulpwood is the major source of income, with construction, highway maintenance and skilled trades being secondary sources.

Six months per year is also spent in non-farm work in the Hadashville region. The Manitoba Forest Service, with the Pineland Forest Nursery, Forest Ranger station and the forest access road building program, is the main employer here. Pulpwood is another major source of non-farm income.

Pulpwood is the main source of non-farm income in East Braintree region, where construction and the Manitoba Forest Service are secondary

sources. The time spent in non-farm work is limited to 6 months by the seasonal nature of the work and would increase if employment of longer duration was available.

The small cultivated areas per farm in the three northern regions are largely responsible for low farm incomes and the accompanying need for alternate income sources. This is shown in a comparison of Plates 22 C and 22 D in the Economic Atlas of Manitoba, which gives the value of livestock per farm and the value of livestock per acre of farmland by census subdivision.

Land-Use Problems and Trends

Grain marketing is not a serious problem in the Whitemouth River valley as production is small and only a few farmers derive their main income from this source. But the cost of farm labor is prohibitive forcing many small farm operators to buy much machinery, such as swathers, combines, and hay balers which is not used to its full potential thus increasing the cost of production. Insufficient drainage is a serious problem. It appears as high ground-water tables and undrained depressions.

Low soil fertility, related to surface texture and drainage, is a problem in the Hadashville and East Braintree regions. However, the crop rotation scheme with its emphasis on hay, is well suited to the area. Organic matter added by the hay sod, increases soil fertility and serves the additional purpose of improving the physical condition of fine-textured soils.

Weed control is made difficult by the use of barnyard manure and the presence of weed-infested, abandoned land in the southern three regions. Couch grass, wild oats and thistles are particularly troublesome in the farms of the Elma region which specialize in grain.

The main trends in the area are toward more beef cattle; more widespread use of commercial fertilizers, particularly in the Elma region; and to an increase in farm size, mainly through rentals, except in the Whitemouth River region where direct sale is the usual method. The outstanding trend in the East Braintree region is toward non-farm work.

In May 1961, farmers of the Hadashville area, initiated, with the assistance of the Manitoba Department of Agriculture, a trial plot for the production of small fruits, particularly strawberries. This locality was chosen because of suitable soil in some areas, and an adequate labor supply. There is a possibility that this crop will turn the small farms of the area into economic units.

In the future, it is probable that the Whitemouth region will continue as an area of relatively high and stable income. Farm units will become both more economic and efficient as their size is increased.

The need for larger farms is more acute in the Elma region. The Mennonite group in the area will doubtless prove, as it has in the past, active in land acquisition for the formation of larger farms. It is probable that farms on the poorer land of the region which are now owned by elderly persons, will be abandoned or used for forage production as they become incorporated with other farms.

Unless the production of small fruits develops on a large scale in the Hadashville and East Braintree regions it is almost inevitable that farm units will become much larger in the Hadashville region and that farms will be abandoned in the East Braintree region.

References

Connor, A. J.
1939: Climate of Manitoba. *Economic Survey Board of Manitoba*, Winnipeg, 9-12.

Johnston, W. A.
1921: Winnipegosis and upper Whitemouth River areas, Manitoba, Pleistocene and Recent deposits. Canada, *Department of Mines*, 25-32.

Manitoba
1960: Economic Atlas of Manitoba (ed: T. R. Weir). *Department of Industry and Commerce*, p. 4.

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AREA MEASUREMENT ON PRINCE EDWARD ISLAND LAND-USE MAPS

J. B. McClellan

ABSTRACT: This paper outlines a method of area measurement used in the regional analysis of Prince Edward Island. Land-use maps of the island at a scale of 1:50,000 were covered with a grid of one-mile squares as unit-areas. The area of each land-use category within a unit-area was measured with a dot planimeter. The data were processed by an IBM 650 computer to obtain twenty-seven percentage and acreage figures for each unit-area. These percentages and acreages were then plotted on choropleth-type maps which proved to be useful tools for the regional analysis of the island.

RÉSUMÉ—Dans cette étude, l'auteur ébauche une méthode de mensuration des superficies que l'on a utilisée au cours de l'étude régionale de l'île du Prince-Édouard. On a d'abord couvert les cartes au 50,000e sur l'utilisation des terres, d'un quadrillage dont l'unité de superficie était d'un mille carré. Dans chaque secteur, on a mesuré, à l'aide d'un planimètre à pointillé, la superficie de chaque catégorie d'utilisation des terres. En interprétant ces données à l'aide d'une calculatrice électronique IBM 650, on a obtenu pour chacun des carrés 27 valeurs exprimées en pourcentages et en superficie agraire. Puis, on a reporté ces valeurs sur des cartes «de type choropleth», qui se sont révélées d'ailleurs fort utiles pour exécuter l'étude régionale de l'île du Prince-Édouard.

The production of a series of regional explanatory memoirs to accompany published land-use maps is an important part of the land-use mapping program of the Geographical Branch. Preparation of the first memoir, covering Prince Edward Island, began late in 1960 (Raymond, McClellan and Rayburn, in press). This paper outlines a method of area measurement used in that study to translate the raw data contained on the original land-use maps into a quantitative form which could be used in the construction of a large number of percentage and acreage maps, as well as in the determination of regional boundaries.

The basic materials for the study were twenty-five National Topographic Series map sheets at a scale of 1:50,000, on which had been plotted the distribution of the twenty land-use categories used in the survey. These sheets were compilations derived from field observations mapped on air photographs during the 1958 and 1959 field seasons. The distribution of the categories on the maps presented complex patterns to those attempting to describe their arrangement, and the maps did not convey anything more than unprecise impressions of the actual acreages and densities of crops, both for the island as a whole or its various parts. Clearly, if the analysis was to proceed beyond the stage of hazy generalizations, some method was needed by which the wealth of distributions and relationships shown on the maps

MS submitted October 1962.

could be converted into quantitative form. To take a simple example, it is evident that the statement "In subregion A, grain acreages comprise 62 per cent of the total cropland acreage", derived from quantitative analysis, conveys a clearer description to the reader than the statement "There is a heavy concentration of grain in subregion A", derived from visual inspection of the same basic data.

The use of census material would have been one solution to the problem of obtaining quantitative data.* Figures from the 1956 Census of Agriculture were available for each of the 67 lots and the two royalties, the tiny statistical units into which the island is divided. Though used extensively throughout the monograph, complete reliance could not be placed upon census data for two reasons. First, census figures relate only to agricultural land use, whereas the memoir was concerned with the totality of land use in the area; in Prince Edward Island total area exceeds total farmland by more than 200,000 acres, with urban land uses making up only a small part of this difference. Secondly, categories used in the census differ significantly from land-use categories—there are no categories in the census, for example, corresponding to the grassland categories on the land-use maps, yet a knowledge of the total acreage and distribution of grassland is essential to any discussion of land abandonment.

What was needed was a method by which the areas of the various categories on the land-use map could be measured rapidly, with the figures derived from measurement being plotted as percentage and acreage maps. Areal measurement on a unit-area basis proved to be the most satisfactory solution to the problem. Through the use of unit-areas and measurements made with a dot planimeter it was possible to construct a large number of quantitative maps pertaining to land use in a relatively short period of time.

Construction of the Grid

After many trial-and-error approaches, a unit-size of one square mile was selected. As a result, for every square mile of the island's land surface, the area of each category within the unit could be measured and various percentages, such as the percentage of the total area under woodland, could be calculated. These percentages could then be plotted on small-scale choropleth-type maps.

*For an excellent example of the use of census statistics to describe historical land-use patterns, see A. H. Clark: Three Centuries and The Island, University of Toronto Press, Toronto, 1959.

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The island was completely covered with a grid of one-mile squares (McClellan, Figure 1, in pocket). The grid was first drawn up on 1:50,000 N.T.S. sheets. A tracing of the grid for each sheet was made on transparent acetate and the acetate was then superimposed upon the corresponding 1:50,000 land-use sheet. The grid system was constructed with the meridian of 46°30' West as the base. Since field patterns follow the general NW-SE alignment of the original land survey, the unit areas seldom coincided with visible features of the landscape, such as road allowances or field boundaries. In this respect it differs from the grid used by Krueger in his study of the Niagara fruit belt (Krueger, 1959). On the island, to have tied the grid down to the road pattern would have necessitated too great a variation in unit-area size.

Each unit on the grid was assigned an identifying number. The total number of squares needed was 2,402. Not all of these, however, contained 640 acres of land surface, due to the great length of coastline around the island. Wherever possible, coastal units were grouped to approximate 640 acres; despite this grouping, the areas of many units in coastal regions were considerably less than one square mile.

Area Measurement

Areas of the land-use categories within each square were measured with a dot planimeter, on which one dot represented 10 acres of land. Because of the small areas involved, the five urban categories were grouped as one. Thus, for each square, the areas of 16 mapping categories were measured, although no square was encountered on which all 16 categories were present.

The dot planimeter was used in full knowledge of the fact that it is not as accurate as many other area-measuring devices (Gierhart, 1954). It was believed that the rapidity with which the island could be measured using the dot planimeter more than offset the resulting inaccuracies. It must be stressed that a very high degree of precision was not the goal, but rather, the objective was to obtain as rapidly as possible detailed choropleth maps showing areal variations for a wide variety of ratios. Acreage figures derived from the measurement are only approximations, since error is present not only through the choice of the measuring device but also as a result of the transfer of data from the field photographs to the 1:50,000 land-use maps. In addition, for the island as a whole or its subregions, the total area covered

by farm buildings and associated lawns and garden plots, roads, railways, etc. must be considerable, yet these cannot be measured from the land-use maps.

Processing the Data

The area of each land-use category within each unit-area was entered upon tabulation sheets. In the case of unit-areas which were transected by the boundary of a lot, the areas on each side of the boundary were measured and entered separately. This permitted the tabulation of the data by lots, affording an opportunity for comparison with census data.

When the measurement process was completed, the figures from the tabulation sheets were coded and put on standard IBM punch cards for processing on an IBM 650 computer. The desired acreages and percentages were outlined and a computer program was written. The data were then processed on the computer. The following tabulation lists the 27 acreages and percentages that were obtained for each unit-area and for each lot, and also indicates the composition of the various categories for which percentages and acreages were derived.

List of Acreages and Percentages, Processed by IBM 650 Computer -by unit-area and by lot

Acreages

1. Total area—A,B,C,D,E,F,G,H,I,J,K, L,M,N,O,P
2. Agricultural land—B,C,D,E,F,G,H,I,J
3. Improved agricultural land—C,D,E, F,G,H
4. Cropland—D,E,F,G,H
5. Tilled cropland—D,E,F,G
6. Potatoes—E
7. Grain—F
8. Hay—G
9. Improved pasture —H
10. Open grassland—I
11. Woodland —K,L,M,N
12. Dense woodland—K
13. Second grade woodland—M,N
14. Other land —O,P

Percentages

1. Agricultural land/Total area
2. Woodland/Total area
3. Other land/Total area
4. Improved land/Agricultural land
5. Cropland/Agricultural land
6. Open grassland/Agricultural land
7. Tilled cropland/Agricultural land
8. Potatoes/Improved land
9. Grain/Improved land
10. Hay/Improved land
11. Improved pasture/Improved land
12. Dense woodland/Total woodland
13. Second-grade woodland/Total woodland

Mapping Categories

A. Urban
B. Blueberries
C. Orchard
D. Horticulture
E. Potatoes
F. Grain
G. Hay
H. Improved pasture
I. Open grassland
J. Scrub grassland
K. Dense woodland
L. Open woodland
M. Scrub woodland
N. Cutover, burntover woodland
O. Unproductive land
P. Swamp

The results were obtained from the computer on printed sheets so arranged that, through the use of a cardboard screen, the results could readily be plotted on a 1:250,000 base map on which the grid was outlined.

Using the Results

From the data processed on the computer it was possible to plot a large number of choropleth maps of percentages and dot maps of various crop acreages. The most important of these maps are reproduced in the memoir. Figure 1 is an example of the type of map produced by this method of area measurement. Superimposition of the various maps also aided greatly in the drawing of regional boundaries. Once the regional boundaries had been drawn, regional acreage totals were obtained by a simple process of addition.

Total time involved in the project was approximately 140 man-days. Of this total, 60 days were spent in the construction of the grid and the actual area measurement, and an additional 80 days were needed to record the figures from the computer on base maps and to construct the final dot and percentage maps. It will be appreciated that, if access to the computer had not been available, the project would not have been undertaken. The computer was able to perform in a matter of minutes approximately 200,000 computations; if done by hand the amount of time needed for these operations would have been far too long to be feasible.

The method described in this paper was used to extract a large amount of numerical data from detailed land-use maps. The method would seem to be of considerable value in cases where a large number of percentages or acreage figures are derived for a large number of small areas and only a moderate degree of precision is required.

References

Gierhart, J. W.
1954: Evaluation of methods of area measurement. *Survey and Mapping*, v. XIV, no. 4, 460-465.

Krueger, R. R.
1959: Changing land-use patterns in the Niagara fruit belt. *Trans. Roy. Can. Inst.*, v. XXXII, pt. II, 39-140.

Raymond, C. W., McClellan J. B. and Rayburn J. A.
1963: Land utilization in Prince Edward Island. *Geographical Branch*, Ottawa. *Memoir, in press.*

PROGRESS OF BREAK-UP AND FREEZE UP ALONG THE MACKENZIE RIVER

J. Ross Mackay

ABSTRACT: Historical records of freeze-up and break-up and aerial observations of these events have been collected for the Mackenzie River between Great Slave Lake and the Beaufort Sea. These data have been studied with reference to the progress of ice formation and disintegration, the effects of break-up on flooding in the Mackenzie Delta, and the influence of flow travel time on freeze-up and break-up dates.

The progress of break-up and freeze-up along the Mackenzie has been analyzed both by standard statistical procedures (Wilcoxon matched-pairs signed-ranks test, and Kendall coefficient of concordance) as well as by aerial mapping (1959, 1961, and 1962). Results show that the Mackenzie first opens up at its outlet from Great Slave Lake and also where major tributaries enter it. Break-up is nearly simultaneous between Fort Simpson and Fort Good Hope or even Arctic Red River, but there is normally a delay of a few days between Fort Providence and Fort Simpson. The Mackenzie Delta break-up is complex because the southwestern part is controlled by the opening up of the Peel River and mountain rivers. Freeze-up is more orderly than break-up as it progresses fairly regularly upstream from the mouth to Great Slave Lake.

The variability of channel break-up and numerous ice jams caused severe flooding in the Mackenzie Delta during the latter part of May and early June 1961. Visual estimates suggest that over 95 per cent of the delta was under water.

The estimated flow travel time between Great Slave Lake and the Beaufort Sea is 15 to 20 days during the open season. The progress of break-up cannot be directly related to the normal flow travel time due to the changes in stage that occur during the break-up period. Water temperatures and flow travel time do not provide a satisfactory explanation for the progress of freeze-up, and further study on the heat budget of the Mackenzie River is necessary.

RÉSUMÉ—La présente étude chronologique reconstitue par l'interprétation des photos aériennes le double phénomène du gel et du dégel dans ce tronçon du fleuve Mackenzie qui s'étend du Grand lac des Esclaves à la mer de Beaufort. L'auteur examine ces données en fonction de la formation et de la désagrégation de la glace, des effets du dégel sur l'inondation du delta du Mackenzie et de l'influence de la vitesse de l'écoulement des eaux sur les dates où se produisent l'embâcle et la débâcle.

La progression de ces deux phénomènes le long du Mackenzie a été étudiée à la fois par des méthodes statistiques classiques (essai de Wilcoxon, et coefficient de concordance de Kendall) et par cartographie aérienne (1959, 1961 et 1962). Les résultats démontrent que le fleuve se dégage d'abord à sa source au Grand lac des Esclaves et au confluent de ses principaux affluents. La débâcle survient presque en même temps entre Fort Simpson et Fort Good Hope ou même Arctic Red River, mais elle a lieu d'ordinaire à Fort Simpson quelques jours plus tard qu'à Fort Providence. Dans le delta du fleuve, la débâcle est compliquée, car elle dépend, dans la partie sud-ouest, de celle de la rivière Peel et des rivières qui coulent des montagnes. L'embâcle est plus ordonné que la débâcle, car il progresse assez régulièrement vers l'amont depuis l'embouchure jusqu'au Grand lac des Esclaves.

La variabilité de la débâcle dans le chenal et de nombreux embâcles ont causé de fortes inondations dans le delta à la fin de mai et au début de juin 1961. On a estimé à vue que le delta était inondé dans la proportion de plus de 95 p. 100.

On estime qu'au cours de la saison où le fleuve est libre de glace, il faut de 15 à 20 jours aux eaux pour descendre du Grand lac des Esclaves à la mer de Beaufort. La progression de la débâcle ne saurait se rattacher directement

MS submitted 15 July 1962.

à la durée normale de cette descente, car il y a des variations de niveau durant la débâcle. Les températures de l'eau et la durée de la descente ne pouvant à elles seules expliquer la marche de l'embâcle, il faudra poursuivre plus avant l'étude du bilan de la chaleur du fleuve.

INTRODUCTION

The northward-flowing Mackenzie River, one of the world's great rivers, is of paramount importance to the economy of northwest Canada. In the absence of roads and railways, the Mackenzie River serves as an arterial transportation route for settlements along both the river and the arctic coast. Almost all the rivers and lakes within the 700,000-square-mile drainage basin freeze over in winter. About two-thirds of the drainage basin is within the limits of discontinuous permafrost, with the northerly part lying in an area of continuous permafrost.

The geographic problems of the Mackenzie River are in many respects similar to those encountered along other arctic and subarctic rivers in countries bordering the Polar and Pacific basins, such as the north-flowing rivers of Siberia, the Amur River along the Sino-Soviet border, and the Yukon River of Yukon Territory and Alaska. In particular, the Mackenzie River has several features in common with the Angara River of the U.S.S.R. For example, both rivers are nearly the same length, both flow northward through permafrost areas, and most importantly, the rivers are the sole outlets of large storage lakes—Great Slave Lake and Lake Baykal. These large lakes tend to maintain an even outflow and have marked effects upon water temperature, break-up, freeze-up, and flooding.

As a rule, in north-flowing rivers, break-up progresses downstream from the headwaters to the mouth. This is not the case with the Mackenzie River (Mackay, 1961a, 1961b, 1962). Break-up and freeze-up along the Mackenzie River have been analyzed by: *1.* standard statistical procedures, and *2.* aerial mapping.

Progress of Break-up

Break-up is usually defined as either the time the river ice starts to move in the spring, or, when the main river ice clears out at the place of observation. Both criteria involve a certain amount of subjectivity. As the available break-up data for the Mackenzie River have been recorded by non-professional observers—private individuals, missionaries, government officials, etc.—caution should be exercised in the interpretation of comparative dates. As far as is known, break-up from Fort Providence to Norman Wells has been defined by the observers as the first movement of ice, even

FIGURE 1. Location map. Mileages are measured from Great Slave Lake.

though it later jammed and movement ceased. At the Ramparts, which are the narrows immediately upstream from Fort Good Hope, break-up has been considered to occur when the ice broke loose and cleared from ice-jams in the narrows. Break-up at Fort Good Hope has referred to the first movement of ice; at Arctic Red River settlement, when the main river ice cleared, even though subsequently ice jammed downstream, as at Point Separation. At Reindeer Station, break-up has been taken as the time when the main ice cleared out of the river in front of the settlement.

In Figure 2 the mean dates of break-up for the 10-year period 1946–1955 have been plotted. The dates have been adjusted, so far as possible, to indicate the first movement of ice. Minor details have been omitted: for example, the Mackenzie River breaks up earlier than shown at the mouth

of Liard River. The mean dates suggest that break-up between Fort Providence and Fort Good Hope is nearly simultaneous, except for a delay in the upstream section between Fort Providence and Fort Simpson. However, mean dates can be suspect in giving average trends, because the means are greatly influenced by extreme dates and accidental errors in the records. In order to compare break-up dates, the Wilcoxon matched-pairs signed-ranks test was used (Siegel, 1956). The Wilcoxon test was selected because it was felt that the differences observed for matched-pairs, e.g. differences in break-up dates for Fort Providence and Fort Norman, should be meaningful when ranked.

The Table shows that mean break-up is significantly delayed downstream from Fort Good Hope compared with the upstream stations. Although there is no significant difference between break-up dates at Fort Providence and Fort Simpson (Mackenzie River above the settlement), the stretch of river between the two settlements is believed to have a delayed break-up. Unfortunately, no historical records of appreciable duration are obtainable for the river section between these points.

Break-up Comparisons, Wilcoxon Test, 1946–1955

	Fort Providence	Mackenzie River (above Ft. Simpson)	Fort Norman	Norman Wells	Fort Good Hope	Arctic Red River	Reindeer Station
Fort Providence		NS	*	NS	NS	**	**
Mackenzie River (above Ft. Simpson)			NS	NS	NS	**	**
Fort Norman				*	NS	**	**
Norman Wells					NS	**	**
Fort Good Hope (settlement)						**	**
Arctic Red River (at Mackenzie River)							**

*—Significant at 5-per-cent level
**—Significant at 1-per-cent level
NS—Not significant at 5-per-cent level

In order to analyze the over-all progress of break-up, Kendall's coefficient of concordance (Siegel, 1956) was used. The test as applied measures the relation of the multiple rankings of stations along the Mackenzie

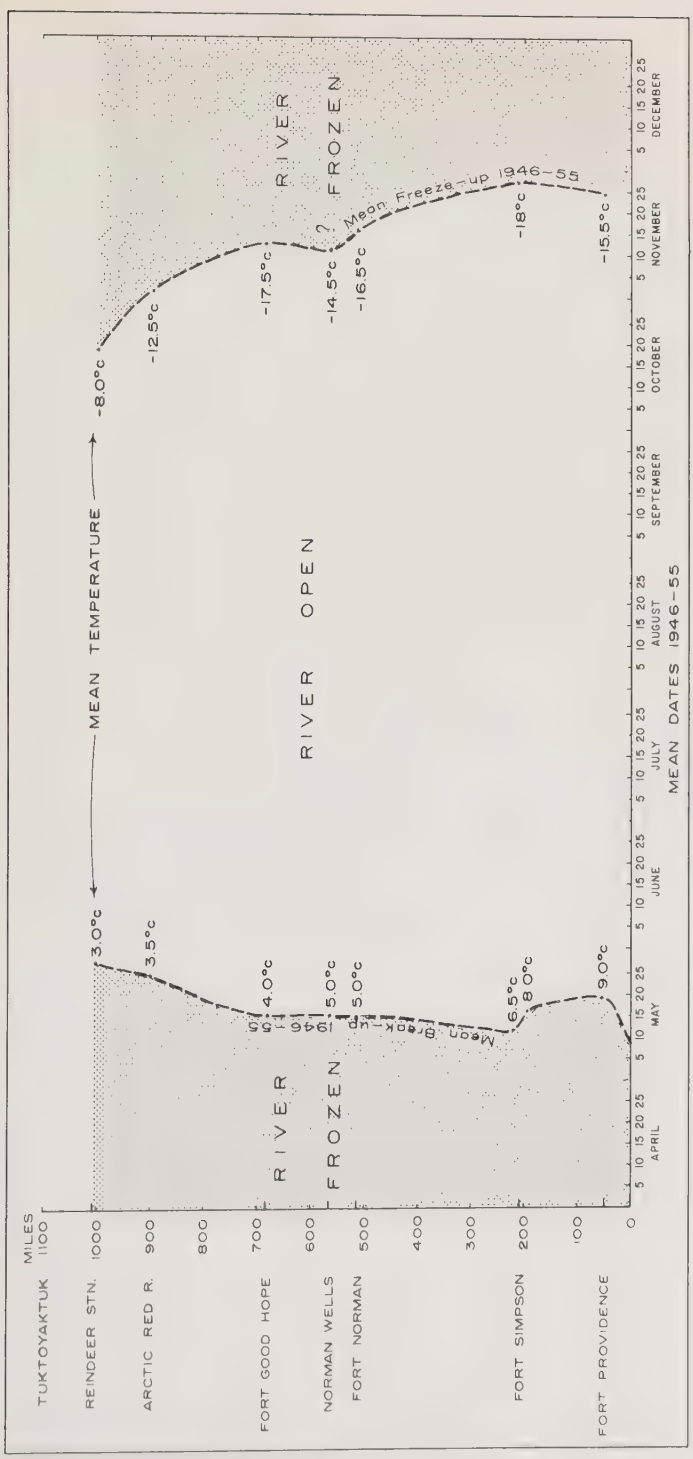

FIGURE 2. Mean data for the 1946 - 1955 period. For the stations along the river the break-up and freeze-up dates have been adjusted, as far as possible, to the same criteria.

River for the 10-year period, 1946–1955. When break-up at Fort Providence, Fort Simpson, Fort Norman, Norman Wells, and Fort Good Hope are ranked for each of the 10 years and the over-all result tested, they are significant at the 1-per-cent level; with Fort Providence omitted, they are not even significant at the 5-per-cent level. The inference is that there is an over-all tendency for a regular break-up trend only when Fort Providence is included. In other words, the progress of break-up between Fort Simpson and Fort Good Hope tends to be variable.

Partial aerial observations of break-up were obtained in 1959 and full observations in 1961 and 1962. On June 2, 1959, the following observations were made by B. C. Cornwall, Geographical Branch, Department of Mines and Technical Surveys, on an airplane flight: the river was ice-free to Fort Good Hope, but much ice had been blown onto the east bank by a northwest wind; from Fort Good Hope downstream to Mile 830, there was a cover of ice with many ice-free side channels; from Mile 830 downstream, there was a cover of almost solid river ice; Middle Channel of the Mackenzie Delta was solid except for some open side channels on the east side and at some bends. By June 10, the main river ice had passed Reindeer Station.

In 1961 and 1962 aerial observations of break-up and freeze-up were made with the co-operation of Pacific Western Airlines on twice-weekly flights between Edmonton and Inuvik. The progress of break-up in 1961 is shown on Figure 3. In the spring, the first signs of break-up were at the west end of Great Slave Lake where there was open water in the two channels between Big Island and the opposite shores. By May 5, there was slight overrunning in narrow bands along both shores between Fort Providence and Fort Simpson. There was considerable overrunning of water along the sides of both the Mackenzie and Liard rivers upstream from Fort Simpson. By May 9, Mills Lake, which is downstream from Fort Providence, was beginning to open and side channels were fully open on the lower Liard River. The Mackenzie tributaries downstream from Fort Simpson were mainly open and there were clear patches in the Mackenzie at some tributary mouths, e.g. off Ochre River, Johnson River, and Redstone River. By May 16, patches of open water in mid-river occurred between Fort Providence and Fort Simpson. From Fort Simpson to Fort Norman, patches were open opposite tributary mouths, and side channels were developing downstream from them. By May 24, the river was clear except for drifting floes from Mile 0 to Mile 80; from Mile 80 to Mile 180, the ice was still fairly solid; from Mile 180 to Mile 285, the Mackenzie River was nearly

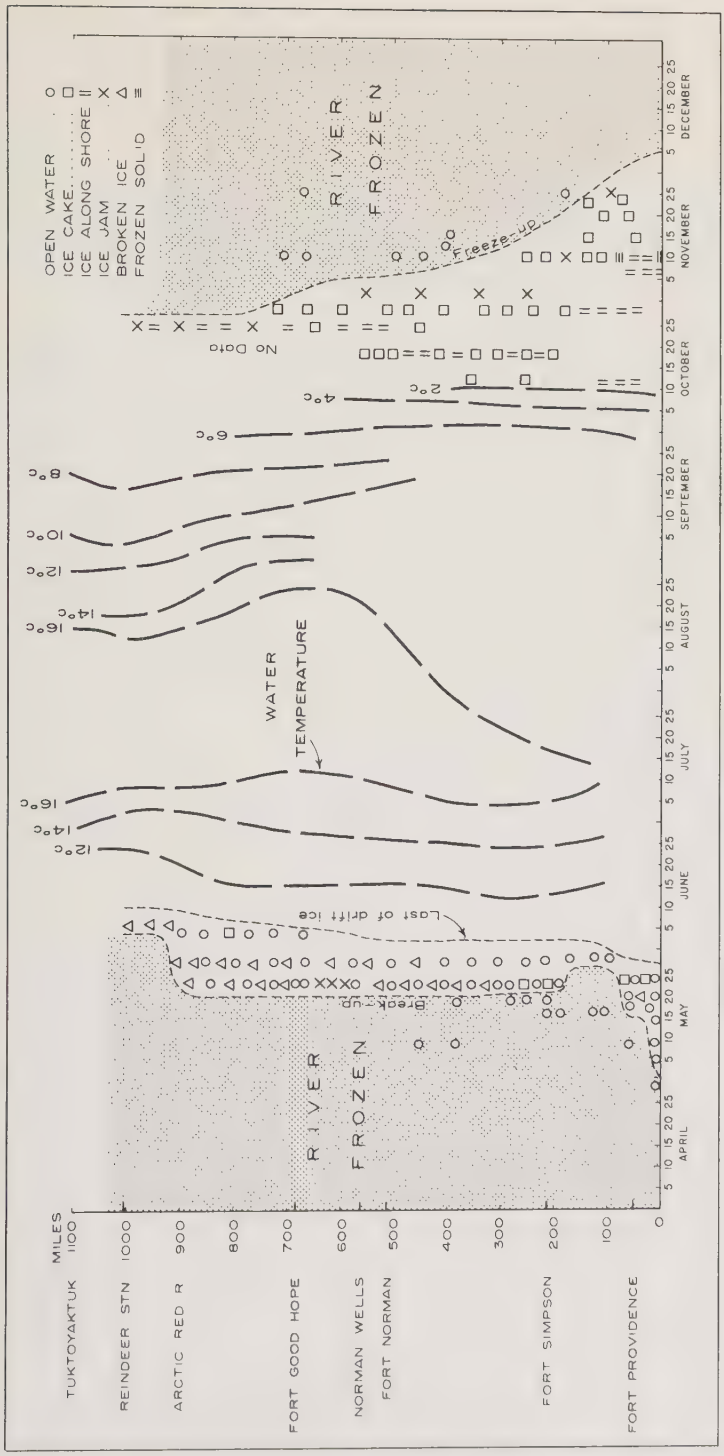

FIGURE 3. Data on break-up and freeze-up for 1961 has come from aerial mapping. The water temperatures are for surface water.

clear of ice as was the Liard River. Broken ice with large open areas extended from Mile 285 to about Mile 640; from Mile 640 to the Ramparts at Mile 680 there was ice backed up with an ice-jam at the Ramparts; from Fort Good Hope to Point Separation there were open areas. By the end of May, the entire river was nearly clear of ice to the Mackenzie Delta, although unbroken ice extended across Middle Channel of the Mackenzie River in the latitude of Aklavik. Within the first few days of June, the delta channels broke up. The pattern of break-up in 1962 was similar to that of 1961 except that it was advanced several days.

A piecing together of the available statistical and air-reconnaissance data suggests that the Mackenzie River first opens up at the outlet on the west side of Great Slave Lake and also where major tributaries enter it. The ice breaks up nearly simultaneously between Fort Simpson and Fort Good Hope or even Arctic Red River, but is normally delayed a few days between Fort Providence and Fort Simpson. The Mackenzie Delta break-up is complex because the southwestern part is controlled by the break-up of the Peel River (not Peel Channel) and mountain rivers such as Rat River which flows into Husky Channel. Peel River floodwaters are released about 10 days before those of the Mackenzie River in the latitude of Fort McPherson. The sequence of break-up, significant at the 1-per-cent level (Wilcoxon matched-pairs signed-rank test) is: Fort McPherson; then one to two weeks later, Lang Trading Post; then several days later, Aklavik; then in several more days, Reindeer Station.

Great Slave Lake is the major hydrologic control of the upper Mackenzie River. The lake volume is estimated to be at least a hundred times that of the total annual inflow from all tributaries or the total annual outflow of the Mackenzie River (Rawson, 1950). Consequently, the lake functions as a gigantic reservoir, maintaining a nearly uniform water level with an annual range of only 3 feet. Great Slave Lake supports an extensive ice cover long after the Mackenzie River is clear of ice. Break-up on Great Slave Lake is not accompanied by an appreciable rise in water level, so no flood surges are transmitted down the Mackenzie River to accelerate the downstream destruction of river ice. Retardation of break-up between Fort Providence and Fort Simpson is probably due to two main factors: the stabilizing effect of Great Slave Lake on Mackenzie River flow, and, the absence of any sizeable tributaries.

Liard River, the first major tributary downstream from Great Slave Lake, enters the Mackenzie at Fort Simpson. Early snow-melt in the

headwaters of Liard River causes it to break up one to two weeks before the Mackenzie. At break-up, Liard River water may cut a wide swath across the still frozen Mackenzie. Liard River ice, augmented by freshly broken Mackenzie River ice, may jam, backing up the river and raising water levels at Fort Simpson as much as 40 feet over night (McConnell, 1888–89, p. 87D). Although flood waters have risen to within a foot of the floodplain on which the Fort Simpson settlement is located, flooding has not occurred during the period of recorded history.

Downstream from Fort Simpson, the tributary streams tend to break up before the Mackenzie River and thus hasten its break-up. In particular, the mountain tributaries are believed to be especially important as early break-up rivers. Arctic Red River flows into the Mackenzie River at the settlement of Arctic Red River. In 47 years of record between 1895 and 1960, Arctic Red River broke up an average of 4.5 days before the Mackenzie River at the settlement. In only 4 years did the Mackenzie River break-up first. The Peel River at Fort McPherson broke up during 16 years of record (in the period 1939 to 1959) an average of 8 days before the Mackenzie River at nearly the same latitude (i.e. at Arctic Red River settlement). Thus the mountain rivers contribute to an earlier break-up of the Mackenzie River.

The estimated mean temperatures for the period 1946 to 1955 at time of break-up are shown in Figure 2. The mean temperatures decrease from south to north. In the Fort Providence–Fort Simpson section, mean temperatures are above 0°C for an average of three weeks before break-up; at Fort Norman–Norman Wells, two weeks; at Fort Good Hope–Reindeer Station, a week and a half. Thus the cumulated degree days above 0°C prior to break-up decreases rapidly downstream from a mean of about 100 degree days in the south to less than 20 in the north. Clearly, the direct role of temperature is subordinate to other related factors such as the amount of snow-melt, run-off, and rise in river level.

Flooding in the Mackenzie Delta

In late May and early June 1961, there was severe flooding in the Mackenzie Delta. Information on the progress of break-up and flooding has been obtained from R. C. Timmins, Department of Northern Affairs and National Resources, Aklavik, N.W.T., and other sources. On May 29, ice broke in front of Aklavik and began to move out followed by large amounts of silt-discolored Mackenzie River 'black ice'. The Mackenzie River

black ice moved through the southwest side of the delta via the 'mouth of the Peel' (where it enters the Mackenzie River) and also through other channels, such as Esau and Enoch channels. Late on May 29 an ice-jam formed at the mouth of Aklavik Channel where it enters West Channel, thus backing up Peel Channel water into the lower portions of Aklavik. The ice-jam formed from ice moving down Peel and Aklavik channels. At noon on May 30, the ice-jam at the mouth of Aklavik Channel broke, rapidly lowering the water level upstream at Aklavik. However, Mackenzie River ice continued to flow and jam, with a resulting rise in water at Aklavik. On May 31, aerial survey showed an unbroken ice sheet across Middle Channel (the largest distributary channel in the delta) downstream (i.e. north) of 68°10' N, which is nearly at the latitude of Aklavik. Middle Channel was plugged with loose ice back to Point Separation; the mouth of the Peel was blocked by Mackenzie River ice, but the Peel Channel itself was open to Aklavik. Half to three quarters of the southwest part of the delta was inundated. Water continued to rise on June 1, until it was 3 feet deep in the middle of the settlement of Aklavik, and reached a height of 16 to 17 feet above low water level. Water levels fluctuated on June 2, 3 and 4, then rose on June 5. Aerial survey showed that ice was moving down Middle Channel at least as far downstream as 68°30' N and was also going out the distributary channels. Over 95 per cent (visual estimate) of the delta was under water. By June 6, flood waters began subsiding. The flooding was the worst encountered in the delta in many years.

Progress of Freeze-up

Freeze-up is usually defined as the time the river freezes over and the ice stops moving or jams even though open holes may persist for some time afterward. So far as is known, the preceding criterion applies to historical records kept at all settlements along the river. Because the variation in freeze-up dates is greater than for break-up dates, the mean values shown for the 1946 to 1955 period in Figure 2 should be used with caution. Freeze-up progresses fairly regularly upstream from the mouth to Great Slave Lake and appears to be more orderly than break-up.

In 1961, although all of the river was open at the end of September, the lakes were then beginning to freeze over. By mid-October, ice cakes were floating down the river, some originating in tributary rivers. Within the three-day period of October 25 to 28, the stretch of river downstream from Mile 800 froze over, after which freeze-up progressed upstream,

although locally open patches were maintained for varying periods after most of the river had frozen over. The 1961 freeze-up was far more regular than is suggested by the mean dates given in Figure 2, although certain irregularities are known to have occurred. The Ramparts consistently freeze over up to 2 weeks before Fort Good Hope, this possibly affecting the late freeze-up immediately downstream at the settlement. The records for Fort Norman and Norman Wells are not internally consistent, so that mean dates may be incorrect by several days.

In the autumn, the tributary rivers hasten Mackenzie River freeze-up. During the summer months, the water temperatures of most of the major tributaries are similar to that of the Mackenzie, but they cool more rapidly after mid-August. Most tributaries feed ice-cakes into the Mackenzie and then freeze up before it.

Flow Travel Time and Progress of Break-up and Freeze-up

In the open season, the water of the Mackenzie River takes an estimated 15 to 20 days to flow from the outlet of Great Slave Lake to the Beaufort Sea. As the total distance is about 1,060 miles, the average rate of flow is probably between 2.2 and 2.9 mph. In the broader lake-like expansions, such as Beaver Lake and Mills Lake, the weak current decreases in stretches of the river to 1 mph. In other sections, as between the Blackwater River (Mile 412) and Old Fort Point (Mile 478), the current is strong, flowing at an average rate of between 6 and 8 mph (Canadian Hydrographic Service, *Great Slave Lake and Mackenzie River Pilot*, 1958, p. 48). This is faster than the current in the Sans Sault Rapids, upstream from Fort Good Hope.

The estimate of the flow travel time of the Mackenzie River has been based upon the log of the patrol boat RCMP *Spalding* which in June 1960 travelled downstream from Fort Smith to Aklavik to Inuvik under the command of Supt. W. G. Fraser. The boat was run at constant engine speed and the elapsed time for 10-mile intervals, periods of stopovers, and delays were recorded. On the assumption that the actual boat speed was the sum of the still-water boat-speed and water speed, an estimate has been made of the water speed. On this basis, the surface flow of the river along the route travelled by the patrol boat took 13.8 days from Great Slave Lake to Aklavik, or about 15 days to Beaufort Sea. The estimated surface flow travel time is shown in Figure 4. For various reasons, such as

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problems involving precise location on a river stretch devoid of landmarks, too much reliance should not be placed on minor changes in slope. The flow increases in speed upon leaving the Great Slave Lake — Fort Providence section and retains this speed until near Fort Simpson. Downstream from Fort Simpson, the current strength gradually increases to about Mile 630 between Norman Wells (Mile 565) and Fort Good Hope (Mile 684). From Mile 750 to the sea, the speed of flow is nearly constant.

The velocity distribution in a channel section depends upon many factors, such as the cross-sectional shape, channel roughness, presence of bends, and river stage. The maximum velocity is usually slightly below the free surface on which a boat travels. The mean velocity of a river therefore, may be less than that of the surface water along a downstream navigation route which tends to follow fast water. Consequently, the mean flow travel time may be greater than that in Figure 4, by possibly 10 to 30 per cent.

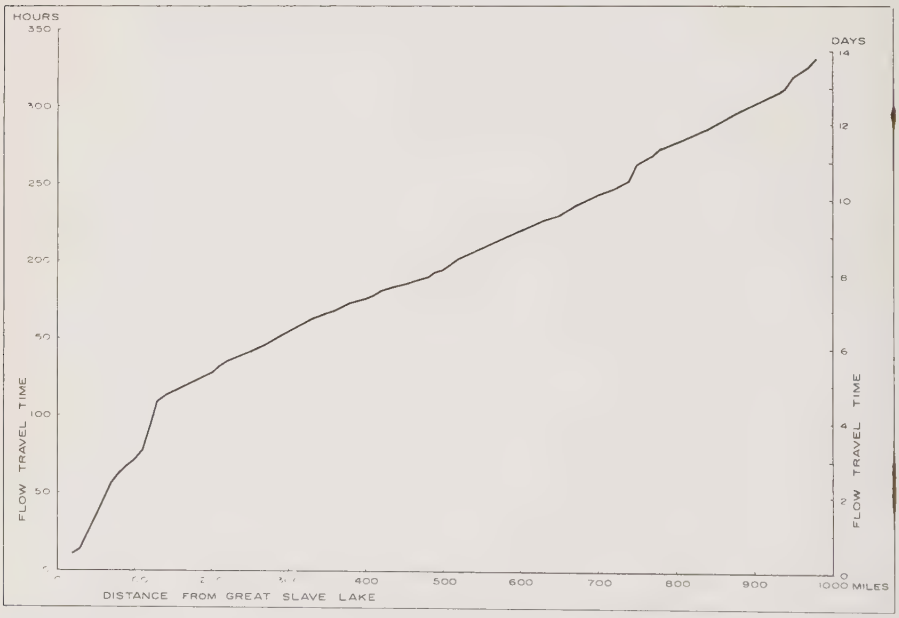

FIGURE 4. The graph shows the estimated flow travel time of surface water at the end of June 1960 Mean flow travel time is probably longer.

The flow travel time plotted in Figure 4 was based on conditions observed from the 25th to 28th of June 1960. This was a month after break-up for the lower section of the Mackenzie and near the peak 1960 summer

discharge of over 600,000 cubic feet a second. Therefore, the flow travel time shown in Figure 4 is representative of above-average summer flow and probably of above-average summer speeds. The accuracy of the data in Figure 4 has been corroborated by using water speeds given in the *Great Slave Lake and Mackenzie River Pilot* (1958). The agreement with the data given in Figure 4 is excellent, but the information in the Pilot is less detailed.

In the stretch from Fort Simpson to Fort Good Hope, the mean time change in break-up is slightly more rapid than the flow travel time of the river (Figures 2 and 4). From Fort Good Hope to Reindeer Station, break-up progess is slower than the flow travel time. Such differences are to be expected, because the river water not only flows downstream, but raises the river level at break-up. Therefore, the progress of break-up cannot be simply related to a downstream passage of a flood surge or the normal flow travel time of the river.

With the co-operation of the RCMP, the Northern Transportation Company, and others, water temperatures were measured along the Mackenzie and some of its tributaries in the summers of 1960 and 1961. The surface-water temperatures shown in Figure 3 have been interpolated from 175 observations. They suggest that the water which froze in late October downstream from Mile 800, left Great Slave Lake with a surface temperature below 2° C. However, the water which froze in the Fort Providence — Fort Simpson area probably left Great Slave Lake only slightly above 0° C. In Figure 2, the mean 1946 to 1955 air temperatures at time of freeze-up indicate that water which froze in the upstream portion had been subjected to considerably lower temperatures and for longer periods than in the downstream section. It is hoped that studies on the heat budget of the Mackenzie River may give explanations of the progress of freeze-up.

SUMMARY

The progress of break-up is delayed in two portions: an upstream section between Fort Providence and Fort Simpson, and, a downstream portion north of Fort Good Hope. Freeze-up, on the other hand, progresses in orderly sequence from the mouth to Great Slave Lake. Tributary rivers tend to accelerate both break-up and freeze-up. The flow travel time of the Mackenzie River is estimated at two to three weeks.

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References

Canadian Hydrographic Service.
1958: Great Slave Lake and Mackenzie River pilot. *Cdn. Hydrog. Serv.*, Dept. Mines and Tech. Surv., Ottawa.

Mackay, J. Ross.
1961a: Freeze-up and break-up of the lower Mackenzie River, Northwest Territories. *in:* Raasch, G. O. (Ed.) *Geology of the Arctic*, v. 2, 1119-1134.
1961b: A study of freeze-up and break-up at Fort Good Hope, N.W.T. *in: Thought*, W. J. Gage, Toronto, 65-71.
1962: Freeze-up and break-up prediction of the Mackenzie River, N.W.T., Canada, (in preparation).

McConnell, R. G.
1888–89: Report on an exploration in the Yukon and Mackenzie basin, N.W.T. *Geol. Surv., Canada*, Ann. Rept., v. 4 (N.S.), 1D-163D.

Rawson, D. S.
1950: The physical limnology of Great Slave Lake. *J. Fisheries Res. Bd.*, Canada, v. 8, 3-66.

Siegel, S.
1956: Non parametric statistics for the behavioral sciences. McGraw-Hill Book Co. Inc.

DETERMINATION OF THE MARINE LIMIT IN EASTERN ARCTIC CANADA

J. D. Ives

Recently, a paper and map were published in this bulletin on the Wisconsin marine limit in Canada (Farrand and Gajda, 1962). It was a first attempt to compile and interpret existing data from a vast tract of little-known country and it succeeded admirably in bringing together much published and unpublished material. The hazards of such an interpretation of sparse, and, in some cases, unprecise data are competently outlined in the text. The paper represented the culmination of the reconnaissance phase of a study of late- and postglacial marine submergence initiated by the Geographical Branch in 1948.

The second phase will involve the systematic and precise survey of raised shore features in selected areas. These include: Melville and Bathurst islands, Foxe Basin-Baffin Island, and Hudson Strait-Ungava Bay, and represent type examples of contrasting glacio-isostatic provinces. Precise survey and ultimate correlation of contemporaneous shore features will eventually permit the construction of actual isobases rather than simple form lines drawn on the marine limit. In addition, correlation between late-Pleistocene glacial and marine phases should be possible in the latter two areas.

In the meantime, continued acceleration of research in all branches of natural science will provide much new data, both as the primary result of geographical studies, and as incidental acquisition by bedrock geologists, botanists, and other natural scientists. Thus the 250 observations on which the map was based will very soon be doubled and, consequently, many modifications of the initial map should be anticipated. One such modification is proposed here, partly because it is rather substantial and lies within the general field area of the Geographical Branch's Baffin Island project, and partly because it solves a problem in the evaluation of the existing map.

The main object of criticism is the 500-foot 'isɔbase' which roughly parallels the eastern coast of Baffin Island, and the 400-foot interpolation which is drawn farther west through Eclipse Sound. Goldthwait (personal

MS submitted October 1962.

communication, 1961) and Robitaille (1961) have obtained figures of 180 and "little more than" 100 feet respectively in the Clyde River vicinity, through which the 500-foot isobase passes. Similarly, Robitaille gives heights of 125 feet for Cape Hooper, 75 feet for Broughton Island, 60 feet for Padloping, and no apparent submergence for Cape Dyer (Robitaille, 1961), all of which lie approximately along the 500-foot isobase.

Examination of air photographs of the Cape Dyer vicinity under high magnification, in conjunction with a map at the scale of 1:40,000 with a 25-foot contour interval (unpublished), reveals that the maximum possible submergence is 85 feet, the height of an apparent raised bay-head bar. Certainly, examination of air photographs without actual field work leaves much to be desired but, by comparison with a similar area (northern Labrador) both in the field and by photograph study, it can be argued that evidence of marine submergence to 500 feet above present sea level should be apparent on the photographs had it occurred. Finally, a visit to the coast north of Cape Adair during August 1962 led to the conclusion that marine submergence did not exceed 100 feet in this vicinity; Falconer obtained a figure of 287 feet* for Tay Sound (Falconer, 1962). The Cape Adair vicinity lies at the seaward edge of a glacial trough and the possibility of a late-phase, outlet glacier reaching sea level, thereby giving an unnaturally low marine limit, cannot be ruled out. This is considered unlikely, however, as the marine forms below the 100-foot level can be traced continually on the air photographs as distinct features for many miles southward, and northward into Buchan Gulf. No marine features can be observed above this level. The uncertainty of the 100-foot figure is due to lack of a satisfactory base level for the aneroid during the short time available in the field. The actual figure is more likely to be close to 60 feet, and certainly not more than 100 feet.

What then are the high-level features which prompted the drawing of the 500-foot isobase? The following discussion illustrates one of the major problems involved in this type of study—the evaluation of data collected by a variety of travellers and scientists.

It is necessary to go back to several original sources. Low states that "along the eastern shores of Baffin Island terraces were constantly seen, which were estimated to rise from 500 to 700 feet above the sea" (Low, 1906, p. 235). Because these heights were estimated from shipboard, Farrand and

*Precise level and staff survey to upper limit of water-washed terrain.

Gajda selected the more conservative figure of 500 feet for use on their isobase map. However, Goldthwait has personally examined such marine terraces as described from shipboard and interprets them as glacio-lateral features (Goldthwait, personal communication, 1961). Such features are conspicuous on the air photographs in some areas and cannot always be differentiated with certainty when considered individually. Usually they can be traced into ridges (lateral moraines) and sometimes into pitted terraces and glacio-fluvial forms. Mathiassen provides a further statement of 'extreme' submergence in the vicinity of Pond Inlet where he describes "a distinct marine terrace——at a height of about 200 m." (Mathiassen, 1933, p. 57) yet it is doubtful from the text that he ever examined this feature on the ground and no evidence is given in support of a marine origin. Indeed, his sole positive evidence for submergence in this area are marine molluscs found at a height of only 10 metres above present sea level. Another member of the Fifth Thule Expedition cites as evidence of marine submergence 'sand with rolled pebbles' on the summit of a mountain in Admiralty Inlet (Laursen, 1946, p. 13). Finally, a passage from a paper by Wordie (1938, 407–408) referring to inner Cambridge Fiord warrants close examination:

> "In the last 10 miles terraces were frequent and these were not confined to low levels as were the terraces found at almost all the fiord heads, but could be seen as high as 800 feet, and at one place on the west side a terrace was observed at a height thought to be as much as 1,500 feet—but we do not think a marine origin was sufficient to explain all the terraces."

Wordie definitely does not state that the terraces *were* of marine origin, nor does he provide a morsel of evidence to support such a thesis. The lower figure, 800 ft., however, appears on the Glacial Map of North America (Flint and others, 1945) and on the Glacial Map of Canada (Wilson and others, 1958) as does the data supplied by Low and Mathiassen. Farrand and Gajda (1962) at least reject the 800-foot figure.

It seems likely, therefore, that the 500-foot isobase is the result of misinterpretation of terraces, seen from shipboard, and inappropriate selection of data in compiling a map, the latter difficulty being particularly hard to guard against. On this basis it is suggested that the 500-foot isobase be struck off the map. This action would then clarify the existing knowledge on the pattern of marine submergence in eastern Baffin Island and serve to resolve some of the loose ends of isobases in the Ungava Bay–eastern Hudson Strait area which do not fit on the existing map. Cursory examination of the isobases in this area serves also to illustrate a second problem in determination of the marine limit from existing data. Previous sources

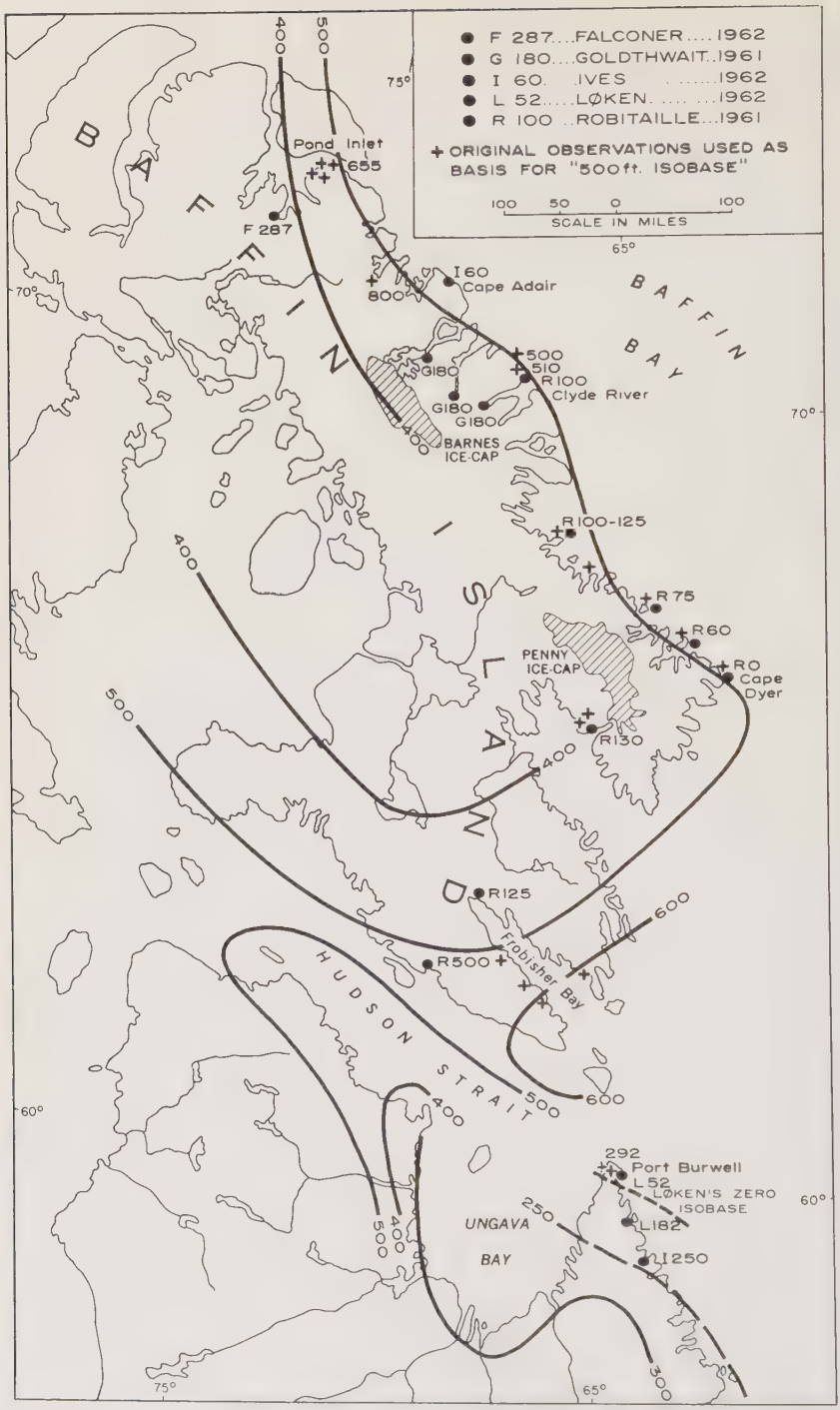

FIGURE 1. Sketch map comparing isobases with conflicting field data. Possibly most of the isobases shown, which have been traced from Farrand and Gajda's map, should be challenged.

already mentioned (Flint and others, 1945; Wilson and others, 1958; Farrand and Gajda, 1962), have placed some weight on the seemingly strong evidence of Nichols (1936) for a submergence of more than 250 feet at Port Burwell. Nichols found marine microfossils in this area. Løken, however, discovered marine macrofossils at various heights between 200 and 900 feet in the area south of Port Burwell and was able to prove conclusively that they were associated with an end-moraine system, the shells having been raised by glacial transport. He was also able to conclude that the marine limit in the Port Burwell vicinity was not more than 52 feet (Løken, 1962; and personal communication, 1962); presumably Nichols' microfossils were emplaced in the same manner as Løken's shells.

The controversy which has arisen over Mercer's and Wengerd's data (Mercer, 1956; Wengerd, 1951; Ward, 1952; Bird, 1959) also indicates the need for careful field investigation in Frobisher Bay before any attempt is made to evaluate the extent of marine submergence there. For the time being it seems advisable to discount the high figures of Wengerd and Mercer and place added weight to new evidence resulting from the work of Løken (1962), Matthews (1962) and Robitaille (1961) to the south. As a temporary measure, therefore, the re-evaluation of the data outlined on Figure 1 is proposed to serve as a working basis for continued research.

References

Bird, J. B.
1959: Recent contributions to the physiography of Northern Canada. *Zeits. für Geomorph.*, Bd. 3, Ht. 2, 151-174.

Falconer, G.
1962: Unpublished report on field work in north-central Baffin Island, 1962. *Geographical Branch*, Ottawa.

Farrand, W. R. and Gajda, R. T.
1962: Isobases on the Wisconsin marine limit in Canada. *Geog. Bull.*, no. 17, 5-22.

Flint, R. F. and others
1945: Glacial Map of North America. Special Paper No. 60, *Geol. Soc. Am.*

Laursen, D.
1946: Quaternary shells collected by the Fifth Thule Expedition, 1921-24, Vol. 1, no. 7, Gyldendalske Boghandel, Nordisk Forlag, Copenhagen.

Løken, Olav
1962: The late-glacial and postglacial emergence and the deglaciation of northernmost Labrador. *Geog. Bull.*, no. 17, 23-56.

Low, A. P.
1906: Report on the Dominion Government expedition to Hudson Bay and the Arctic Islands on board the Neptune, 1903-1904. Government Printing Bureau, Ottawa.

Mathiassen, T.
1933: Contributions to the geography of Baffin Land and Melville Peninsula. *Report of the Fifth Thule Expedition, 1921-24*, vol. 1, no. 3. Gyldendalske Boghandel, Nordisk Forlag, Copenhagen.

Matthews, B.
1962: Glacial and postglacial geomorphology of the Sugluk-Wolstenholme area, northern Ungava. *In* Field Research in Labrador-Ungava, Annual Report, 1960-61, *McGill Sub-Arctic Research Papers*, no. 12, 17-46, mimeo. McGill University, Montreal.

Mercer, J. H.
1956: Geomorphology and glacial history of southernmost Baffin Island. *Geol. Soc. Am. Bull.*, vol. 67, 553-570.

Nichols, D. A.
1936: Post-Pleistocene fossils on the uplifted beaches of the eastern arctic regions of Canada. *Can. Field Nat.*, vol. L, no. 8, 127-129.

Robitaille, B.
1961: Unpublished report on determinations of the marine limit in the eastern Canadian Arctic. *Geographical Branch*, Ottawa.

Ward, W. H.
1952: A note on elevated strandlines of Frobisher Bay, Baffin Island. *Geog. Rev.*, vol. 42, 651.

Wengerd, S. A.
1951: Elevated strandlines of Frobisher Bay, Baffin Island, Canadian Arctic. *Geog. Rev.*, vol. 41, 622-637.

Wilson, J. T. and others
1958: Glacial Map of Canada. *Geol. Assoc. Can.*, Toronto.

Wordie, J. M.
1938: An expedition to north west Greenland and the Canadian Arctic in 1937. *Geog. J.*, vol. 92, no. 4, 385-421.

MAP NOTES

PROVINCE OF ALBERTA 1:760,320, Alberta, Dept. of Highways, *Surv. Br.*, Edmonton, 1962.

This 2-sheet map is an excellent general map of the province and has been used as a base for three other maps—Municipal Districts, Provincial Electoral Divisions, and Judicial Districts, each of which shows the relevant information by means of a colored overprint.

The base map portrays 5 classes of settlements—cities, towns, villages, summer villages, and hamlets, shown by symbol but without reference to population size. Railways and highways are shown, each as a single class; irrigation canals and water features, national and provincial parks, Indian reserves and forest reserves are also included. The map is based on a polyconic projection with a central meridian at 115°00', and was compiled and drawn in accordance with Section H of the Surveys and Expropriation Act (R.S.A. 1955).

FOREST COVER MAP, CAPE SCOTT PUBLIC WORKING CIRCLE, Sheets 1 and 2, 1:63,360, British Columbia, Dept. Lands and Forests, B.C. Forest Service, *Forest Surveys and Inventory Divn.*, Victoria, B.C., 1961.

This 2-sheet map covering the northern tip of Vancouver Island shows the species predominance by colored areas and forest-type descriptions by symbols and letters. Each forest type contains a descriptive label composed of from 2 to 4 symbols, each including the type reference number and age group. The notation also includes a history symbol that details the logging period, selective logging period, burn dates and other information. The base map has a wealth of detail that includes transportation and communication facilities, logging boundaries, dams, power lines, sawmills, mines, and forest service stations.

ONTARIO 1:4,450,000 (approx.), Dept. Mines and Tech. Surv., *Surv. and Mapping Br.*, Ottawa, 1962.

This outline map of the Province of Ontario shows international, provincial, and county or district boundaries. The legend includes an index to counties, and the base includes principal water features and main settlements.

PROVINCE OF NEWFOUNDLAND 1:633,360, Newfoundland, Dept. Mines, Agriculture and Resources, *Crown Lands and Surveys Br.*, St. John's, 1962.

This is a revision of the 1955 edition of the 10-mile map of the province. It includes Labrador as an inset at approximately 1:3,750,000. The map shows provincial and district boundaries, transportation and communication facilities, and settlements, the latter grouped by symbols into towns with a population of more than 1,000 and settlements with populations of 501 to 1,000, 251 to 500, 100 to 250, and under 100.

LAND-USE SERIES: NIAGARA PENINSULA 1:50,000, Dept. Mines and Tech. Surv., *Geog. Br.*, Ottawa.

Welland East.....30 L/14 E.....published 1962

This multicolored land-use map is the sixth sheet in a block of eleven sheets to be published for the Niagara Peninsula. Land-use information is superimposed on an N.T.S.

1:50,000 base map published by the Army Survey Establishment, R.C.E., in 1953. Twenty land-use categories are used: 5 urban; 7 agriculture; 6 grassland-woodland; 1 unproductive; and 1 swamp and marsh.

The map was compiled by the Geographical Branch in co-operation with the Community Planning Branch, Ontario Department of Municipal Affairs. Land-use information was derived from field mapping, from urban land-use information supplied by the Community Planning Branch, and from forest inventory maps supplied by the Ontario Department of Lands and Forests.

(B.V.G.)

Terrain Analysis Series: Isortoq River 1:250,000, Baffin Island, N.W.T., Glacial Features. Dept. Mines and Tech. Surv., *Geog. Br.*, Ottawa.

This multi-colored map (Figure 2 in pocket) is to accompany the paper, "Studies in the physical geography of north-central Baffin Island" pages 5 to 48 of this Bulletin. Since going to press additions have been made to the map which could not be described in the main text of the paper.

Glacial features have been superimposed upon a modified and photographically enlarged base of the southeast quadrant of the N.T.S. 1:500,000 map sheet, Cockburn Land (37 NW and 37 NE). Features shown include end and lateral-moraines, drumlins and till lineations, stripped bedrock occurring along well-delimited lines (meltwater trimlines), till plains with kettles, glacial lake spillways and col gullies, glacial drainage channels, glacial lake shorelines, kame terraces, areas occupied by cross-valley moraines, deltas, sandar, eskers, erratics and striations. The total area of permanent ice is shown, principally the northern half of the Barnes Ice Cap which also receives special treatment. Because of the availability of special air photographs and preliminary maps at 1:50,000 of the northern part of the Barnes Ice Cap, the area occupied between 19 and 23 July 1961 by the remaining 1960-61 snow accumulation is shown in a stippled blue. In addition, the predominant surface drainage on the ice cap is shown; these represent streams, flowing during the melt season, in deep, ice-walled canyons, cut in places to depths of more than 100 feet. Also shown are contours and form lines with a 200-foot vertical interval. The form lines are in broken grey lines and have been interpolated by the compilers. The first form line above Bieler Lake is in error and should be 1,800 feet, rather than 1,700 feet.

(J. D. I.)

BOOK NOTES

Dictionary of Discoveries by I. A. Langras. *Philosophical Library*, New York, N.Y., 1959. 201 p.

Rarely is a dictionary fascinating reading, except perhaps to the lover of words. However, the *Dictionary of Discoveries* is an exception, as it is a delight to turn the pages, and let one's fancy wander through the romantic age of exploration.

The tone of the book is set in the preface, which immediately catches the imagination with the statement "The age of Discovery produced an astounding number of discoveries in both hemispheres, the greatest of which was of course the discovery of America. Later, by the first quarter of the twentieth century, after many trials, expeditions from Europe and from the United States succeeded in discovering the North and South Poles. The uninhabited, frozen continent of Antarctica is now in the process of being explored. The day is not far off when some new Columbus will discover the moon".

The dictionary, although spanning history of exploration, is not chronological, but rather covers the alphabet from Abruzzi to Zintgraff. These two names in themselves indicate one of the major contributions of the book; that is, the listing of the lesser known, but no less worthy, of the explorers. It is a valuable reference book which should be on the desk of everyone interested in the geography of exploration.

(F.A.C.)

Great Lakes Basin. Publication No. 17 of the American Association for the Advancement of Science, Washington, D.C. 308 p. Price: $7.50.

Few natural resources are so intimately shared by Canada and the United States as the Great Lakes basin. The importance of the basin in the affairs of men has long been recognized, with special emphasis being placed recently with the completion of the St. Lawrence Seaway.

In December, 1959, a symposium on the Great Lakes basin was held in Chicago, under the aegis of the American Association for the Advancement of Science and the Geological Society of America. This volume contains most of the papers presented, in a modified form as is usual for the publication of symposia papers.

Although, as the editor has wisely observed, "collections of this type are rarely completely representative, and this one is not in the favored minority", never-the-less it is a remarkable contribution. A wide range of topics are discussed including "material on pure and applied science, accounts of new research and reviews of material published elsewhere, historical and social studies, and pleas for concentrated and vigorous action".

The geographer, no doubt, will be especially interested in the papers on: drainage and climate, recession of Great Lakes' shorelines, the land-use pattern, development of the transportation network, and the use of the Great Lakes for recreation. It is hardly fair, however, to single out these papers for special mention, as every paper in the collection is worthy of attention. This book is invaluable for anyone interested in the problems and future of the geographical heart of the North American continent.

(F.A.C.)

Glaciers of Northern Baffin and Bylot Islands, N.W.T., by G. Falconer. *Geogr. Br.*, Dept. of Mines and Tech. Surv., Ottawa. Geographical Paper No. 33, 31 p., maps, illus. Price: $2.00.

During the International Geophysical Year a number of projects concerned with the various aspects of glaciology in Canada were initiated. A major difficulty in the discussion of Canadian glaciers arose because most of them were unnamed and often not precisely mapped. Partly to overcome these difficulties, and in response to a recommendation of the International Union of Geodesy and Geophysics, an inventory of Canadian glaciers was begun during the International Geophysical Year, and was carried out, with support of the National Research Council and the Defence Research Board of Canada at the Geophysical Laboratory of the University of Toronto under the supervision of Professor J. T. Wilson.

Since that time the Geographical Branch has continued and expanded the study as part of its analysis of terrain conditions in Canada and its glaciological research program. This paper is the first publication in a regional series planned on Canadian glaciers. It has been compiled from old and new photographs and maps, literature, and air photographs. In all 59 glaciers of northern Baffin and Bylot islands are discussed, and 42 figures are given, many showing changes based on 1948 and 1958 RCAF air photograph coverage.

(F.A.C.)

Stefansson, V. NORTHWEST TO FORTUNE. *Duell, Sloan & Pearce*, New York, 1958, 356 p., maps, index.

Dodge, E. S. NORTHWEST BY SEA. *Oxford Univ. Press*, N.Y., 1961, 348 p., maps, bibliog., index.

As the title implies, *Northwest by Sea* stresses the marine explorations leading to the discovery of sea routes between the Atlantic and Pacific, north of the American continents. Numerous well-written books on the same theme have appeared in recent years, but few provide the detail of *Northwest by Sea* for the voyages prior to the extensive naval operations following the Napoleonic Wars. These 19th century attempts on the Passage are adequately considered (though they begin only on p. 235), but the main appeal of the book to the historian or geographer lies in the accounts of the more obscure, non-wintering expeditions, such as Swaines' two voyages in the *Argo* in 1753 and 1754.

Stefansson's book emphasizes the motive of commercial success inherent in the discovery of the cheapest and shortest route between Europe and China, whether by land, sea or air. *Northwest to Fortune* also discusses the background and accomplishments of the Merchant Adventurers and the naval expeditions, but unlike Dodge's book, also describes the expansion of the fur trade in the interior. The accounts of the explorations of Bell, Murray and MacDougall through the various passes from the plains to the Yukon and Alaska are of particular value.

The different points of view of the two books make them complementary rather than competitive; both are scholarly reference texts with high standards of accuracy and thoroughness.

(J.K.F.)

SURFICIAL GEOLOGY OF THE ELBOW MAP-AREA, SASKATCHEWAN. J. S. Scott, *Geol. Surv. Canada*, Paper 61-15, 1962, 10 p. plus map. Price: 50 cents.

The report deals with the surficial geology of the area about the South Saskatchewan dam. The various physical characteristics of the deposits are briefly discussed. A section on the glacial history of the area deals with the withdrawal of the Laurentide glacier, and seven stages of recession are delimited, based upon field observations of the disposition of glacial melt-water channels, end moraines, and other frontal forms. A map on the scale of one inch to four miles is included. The report is a condensed version of a Ph.D. thesis.

(J.T.A.)

RAW MATERIALS OF CANADA'S MINERAL INDUSTRY, by W. D. McCartney, S. C. Robinson, H. R. Steacy, R. J. Traill and D. R. E. Whitmore. Compiled by R. J. Traill. *Geol. Surv. Canada*, Ottawa, 1962. Paper 62-2. 87 p. Price: 50 cents.

"This booklet comprises short descriptive notes on many of the more important minerals, ores, fuels and rocks that are the raw materials of the mineral industry of Canada." Described under 76 product headings in alphabetical order, information is provided for each product on its use, status of the industry, mineralogy and geochemistry, type of deposits, distribution, future outlook and potential sources. The main purpose of these notes is to accompany a collection of 120 specimens,* and the notes are keyed in the list of contents and the index to the numbers in this collection.

(J.K.F.)

*Obtainable from the Director, Geological Survey of Canada, Ottawa. Price: $25.00 postpaid but to addresses in Canada only.

GEOGRAPHICAL BULLETIN

No. 19 May 1963

In this issue:

Physical geography of north-central Baffin Island.

Descriptive analysis of cross-valley moraines in north-central Baffin Island.

Land abandonment in Prince Edward Island.

Land utilization in the Whitemouth River valley, Manitoba.

Area measurement on Prince Edward Island land-use maps.

Break-up and freeze-up along Mackenzie River.

Marine limit in eastern arctic Canada.